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ABSTRACT

This book is intended to help teachers fulfill the need for children and future leaders to understand issues of global change and the science that lies behind them. Important changes are occurring in several of the earth's subsystems. The changes are thought to be the result from the expanding use of technology for the improvement of living standards, increased consumption of fossil fuels, and the growth of the human population. The book is divided into three sections. The first contains teaching materials targeted at the middle school level. The second contains materials for use primarily in high school science classes including biology, chemistry, and physics. The third section contains fact sheets intended for teachers, to assist them in improving their knowledge of a variety of issues in global change. Each activity focuses on Earth as an integrated system and includes an annotated bibliography of useful references. Some of the global change activity topics include: (1) the greenhouse effect and global warming; (2) ozone depletion; (3) shrinking freshwater resources; (4) deforestation and effects on biodiversity; (5) climate modeling; (6) volcanic eruptions; and (7) proxy data for global climate change. (ZWH)

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ED 382 444

Activities for the Changing Earth System

Earth Systems Education
Middle School and High School Activities

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Activities for the Changing Earth System

Curriculum activities for teaching about global environmental changes.

Produced by The Ohio State University under
National Science Foundation grant #MDR - 8954782.
Rosanne W. Fortner and Victor J. Mayer, Co-Directors.

Project Co-Director: Dr. David H. Elliot

Principal Contributing Teachers:
Dan Jax
Don Torma
Tony P. Murphy

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ACKNOWLEDGEMENTS

This resource book was developed under a grant from the National Science Foundation to the College of Education, School of Natural Resources and the Byrd Polar Research Center of The Ohio State University. It includes activities and fact sheets developed under additional grants from the National Oceanic and Atmospheric Administration's National Sea Grant College Program and the Dwight D. Eisenhower program of the Ohio Board of Regents to the School of Natural Resources.

Although it was these financial resources that made the book a possibility it was the human talent, creativity and hard work that made it a reality. The faculty and graduate students of The Ohio State University and teachers from Ohio area schools who had primary responsibility for conceptualizing, writing and editing are listed on the title page. Dan Jax led off the first year, when there were only blank sheets of paper. His was the difficult task of getting those first activities not only conceived, but also workable. Don Torma picked up the globe as Dan returned to teaching at Bexley Middle School. Don continued the efforts of developing additional activities and getting them piloted out in the schools. When he left to return to teaching at Kenston (OH) High School it was Tony Murphy's turn, fresh off the plane from Ireland. He contributed additional activities and performed the creative and arduous task of final editing and layout. The common thread throughout the three years was Rosanne Fortner who personally developed many of the middle school activities in addition to supervising the editing and formatting of the final product. Without her there would not be a book.

These exceptional individuals made it happen. However there were extensive behind the scenes efforts of many teachers and scientists who offered ideas through seminars and courses held over the three years of the project. Special efforts in conceptualizing and developing activities were made by Don Hyatt, Worthington (OH) Kilbourne High School; Bill Steele, Marysville Middle School, Marysville, OH; Nancy Small and Shirley Brown, Columbus City Schools, OH. Jiang Maan, now a professor of education in Taiwan, assisted in developing several activities. Special contributions in science content were made by David Elliot, and Ellen Mosley-Thompson of the Byrd Polar Research Center. David was a co-principal investigator on the project and provided exceptional insight and scientific background on many of the global change issues. He reviewed plans and early versions of activities for their scientific accuracy and importance. Ellen made special contributions to the science of many of them indirectly through her Global Change Seminars taken by Dan Jax, Tony Murphy and Don Torma. In addition she was always open to questions and discussions relating to the content of activities. Don Hyatt, Dan Jax, and Bill Steele piloted-tested activities in their high school and middle school classes. Other activities were tried out among teacher groups in several PLESE workshops held in various places around the country and in Great Lakes Education workshops held in Ohio and Michigan. It is this reality testing that has been so important in ensuring that the activities are not only good science, but are also teachable.

Finally, we acknowledge Lauren Farr and Sandra Born of the Ohio Cooperative Extension Service. Lauren developed the climate game board and other complex graphics, as well as counselling the project on many design questions. Sandra skillfully designed the cover of this publication.

INTRODUCTION

The *First Earthrise, Apollo 8, 1968*, the photograph taken by William Anders appearing on the cover of this book, has provided a theme for curriculum development efforts in Earth Systems Education. The photograph marks a watershed in knowledge and concern about our Earth. Partly as a result of our greatly enhanced technology exemplified by the ability to take this photograph; our knowledge of planet Earth has changed dramatically since the last major curriculum development efforts in the late 1960's and early 1970's. We now realize that there are important changes occurring in several of the Earth's subsystems. These changes are thought to result from the expanding use of technology for the improvement of living standards, increased consumption of fossil fuels, and the growth of the human population. Mrs. Gro Harlem Brundtland, Prime Minister of Norway and the Chair of the World Commission on Environment and Development, stated in her keynote speech for the *Forum on Global Change and Our Common Future* held in Washington, DC, in 1989 that:

> We face a grim catalogue of environmental deterioration. We know that forests are vanishing.... We are becoming increasingly aware of the spread of desert land. ..... Good soil is being washed away or eroded at alarming rates. It is estimated that about 150 plant and animal species are becoming extinct every day, most of them unknown to laymen and specialists alike. The stratospheric ozone shield is in danger. And above and beyond all these signs of environmental crisis, the climate itself is threatened.

Political, scientific and social experts at that conference emphasized the need to develop informed leadership and public awareness of issues of global change. This need will continue unabated into the future. Our children and future leaders must understand these issues and the science that lies behind them.

With such an important need, it is of concern that a comprehensive search of curriculum materials designed for middle and high school science classes, revealed relatively few materials related to global change issues. This book is intended to help teachers fulfill the need for more attention to such issues. It is divided into three sections. The first contains teaching materials targeted at the middle school level. The second contains materials for use primarily in high school science classes including biology, chemistry and physics. The third section contains "fact sheets" intended primarily for teachers, to assist them in improving their knowledge of a variety of issues in global change, and in adapting for their classroom use various technologies as an aid in teaching about such issues. In each of the activities we have attempted to include the appropriate science content along with a focus on the Earth as an integrated system. Each activity has an annotated bibliography of useful references.

These materials have been developed with the active involvement of scientists from the Byrd Polar Research Center, teachers from Ohio and Michigan schools, and science curriculum specialists from The Ohio State University. Activities were designed to assist teachers and their students to reach the goals stated in the *Framework for Earth Systems Education*, that immediately follows this *Introduction*. This framework was developed for a National Teachers Enhancement Program (PLESE - Program for Leadership in Earth Systems Education) supported by the National Science Foundation.

Many of the activities illustrate the historical approaches of scientific inquiry that are so

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frequently ignored in standard science teaching materials, yet these are the methodologies that have resulted in our knowledge of global changes and in the development of theories such as evolution and plate tectonics. It is important that citizens understand these approaches to scientific inquiry just as they are expected to understand the experimental and laboratory approaches used by the physicist and chemist. Each activity also demonstrates the linkages between Earth subsystems. Many include elements reflecting the importance of stewardship of our resources and elements of art, music or literature.

Use of the format in each topic is highly recommended. The topic may be taught in a single activity or be divided across a number of activities. Some of the concepts in later activities are dependent on understanding the previous material. All of the topics contain the following sections: Objectives; Earth Systems Understandings (components of the Earth Systems Framework addressed in the activity); Materials necessary; Procedure to be followed; Extensions (ideas for ways to include additional understandings); Teacher Background Information (an annotated list of 2 or 3 excellent references for the activity); and References (a general list of books, scientific and magazine articles) for the teacher and students. Relevant audio-visual references are also cited here. Additional teacher information is located inside brackets within each activity. It is recommended that this information is ommited if the activity is reproduced for students.

Global change activity topics include, but are not limited to: greenhouse effect and global warming, ozone depletion, shrinking freshwater resources, deforestation and effects on biodiversity, climate modeling, volcanic eruptions, and proxy data for global climate change. Following the *Framework* there is a chart produced by National Aeronautics and Space Administration (page vi) which illustrates the time and space scale of Earth processes. This chart would make an excellent overhead transparency master. It could also be used to design a wall-size concept map for the global change activities and Earth processes. The impact of technology on the study of the Earth and on the dissemination of information about the Earth is also addressed by materials in this book.

Integrating the five Earth subsystems (atmosphere, biosphere, cryosphere, hydrosphere and lithosphere) and the seven Earth Systems Understandings is motivating for teachers and students. (Refer to page v for a representation of this integration.) It also offers additional insights into the complex interactions of the world's systems, their influence on each other and on the planet. This approach opens new horizons in science teaching by offering alternatives to the teacher and students. Finally, but most importantly, it may lead to a better understanding of nature, technology's role in today's society, the complex interactions between the different areas of the environment, humans and Earth, the planet we all call home.

We hope that you will find the activities and materials useful in your attempts to modernize your science curriculum. We believe that they will help to ensure that your students become acquainted with some to the great issues today that relate to the appropriate use and care of our Earth systems and accordingly that we will be able to pass on to future generations the benefits that our Earth systems have provided us.

FRAMEWORK FOR EARTH SYSTEMS EDUCATION

UNDERSTANDING #1: Earth is unique, a planet of rare beauty, and great value.

- The beauty and value of Earth are expressed by and for people through literature and the arts.
- Human appreciation of Earth is enhanced by a better understanding of its subsystems.
- Humans manifest their appreciation of Earth through their responsible behavior and stewardship of its subsystems.

UNDERSTANDING #2: Human activities, collective and individual, conscious and inadvertent, are seriously impacting Earth.

- Earth is vulnerable and its resources are limited and susceptible to overuse or misuse.
- Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.
- When considering the use of natural resources, humans first need to rethink their lifestyle, then reduce consumption, then reuse and recycle.
- Byproducts of industrialization pollute the air, land and water and the effects may be global as well as near the source.
- The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.

UNDERSTANDING #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

- Biologists, chemists, and physicists, as well as scientists from the Earth and space science disciplines, use a variety of methods in their study of Earth systems.
- Direct observation, simple tools and modern technology are used to create, test, and modify models and theories that represent, explain, and predict changes in the Earth system.
- Historical, descriptive, and empirical studies are important methods of learning about Earth and space.
- Scientific study may lead to technological advances.
- Regardless of sophistication, technology cannot be expected to solve all of our problems.
- The use of technology may have benefits as well as unintended side effects.

UNDERSTANDING #4: The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

- The subsystems are continuously changing through natural processes and cycles.
- Forces, motions and energy transformations drive the interactions within and between the subsystems.
- The Sun is the major external source of energy that drives most system and subsystem interactions at or near the Earth's surface.
- Each component of the Earth system has characteristic properties, structure and composition, which may be changed by interactions of subsystems.
- Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface.
- Weathering, erosion and deposition continuously reshape the surface of Earth.
- The presence of life affects the characteristics of other systems.

UNDERSTANDING #5: Earth is more than 4 billion years old and its subsystems are continually evolving.

- Earth's cycles and natural processes take place over time intervals ranging from fractions of seconds to billions of years.
- Materials making up Earth have been recycled many times.
- Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
- Evolution is a theory that explains how life has changed through time.

UNDERSTANDING # 6: Earth is a small subsystem of a Solar system within the vast and ancient universe.

- All material in the universe, including living organisms, appears to be composed of the same elements and to behave according to the same physical principles.
- All bodies in space, including Earth, are influenced by forces acting throughout the solar system and the universe.
- Nine planets, including Earth, revolve around the Sun in nearly circular orbits.
- Earth is a small planet, third from the Sun in the only system of planets definitely known to exist.
- The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes.
- The rotation of Earth on its axis determines day and night.

UNDERSTANDING #7: There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

- Teachers, scientists and technicians who study Earth are employed by businesses, industries, government agencies, public and private institutions, and as independent contractors.
- Careers in the sciences that study Earth may include sample and data collection in the field and analyses and experiments in the laboratory.
- Scientists from around the world cooperate and collaborate using oral, written, and electronic means of communication.
- Some scientists and technicians who study Earth use their specialized understanding to locate resources or predict changes in Earth systems.
- Many people pursue avocations related to planet Earth processes and materials.

The development of this framework started in 1988 with a conference of educators and scientists and culminated in the Program for Leadership in Earth Systems Education. It is intended for use in the development of integrated science curricula. The framework represents the efforts of some 200 teachers and scientists. Support was received from the National Science Foundation, The Ohio State University and the University of Northern Colorado.

For further information on Earth Systems Education contact the Earth Systems Education Program Office, Department of Educational Studies, The Ohio State University, 29 West Woodruff Avenue, Columbus, OH 43210.

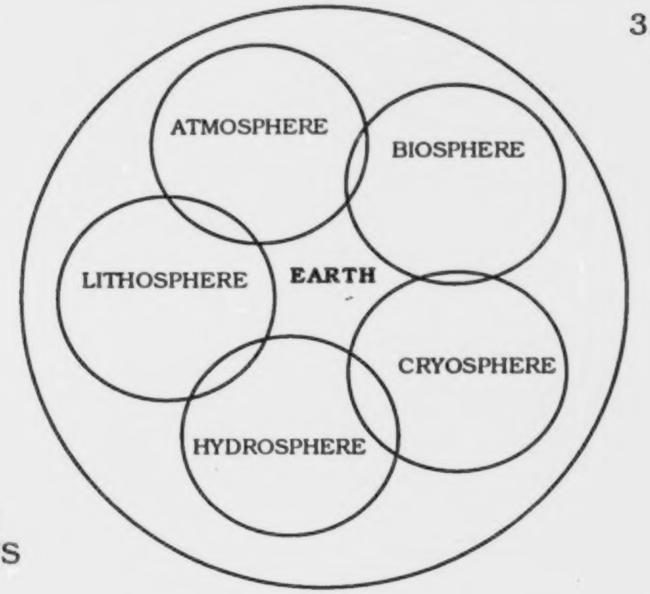
EARTH SYSTEMS EDUCATION

A MODEL

2. STEWARDSHIP

1. BEAUTY

3. SCIENTIFIC PROBLEM SOLVING


ATMOSPHERE
BIOSPHERE
LITHOSPHERE
EARTH
CRYOSPHERE
HYDROSPHERE

7. CAREERS & AVOCATIONS

4. INTERACTING SUBSYSTEMS

6. PLANET EARTH — A SUBSYSTEM

5. DEEP TIME

Earth Systems Education (ESE) recognizes that the planet Earth is composed of FIVE interacting subsystems or spheres - atmosphere, biosphere, cryosphere, hydrosphere and lithosphere. The systems cannot be isolated, each one influences the other four. From this realization, a framework of SEVEN Earth Systems Understandings (ESU) have been formulated.

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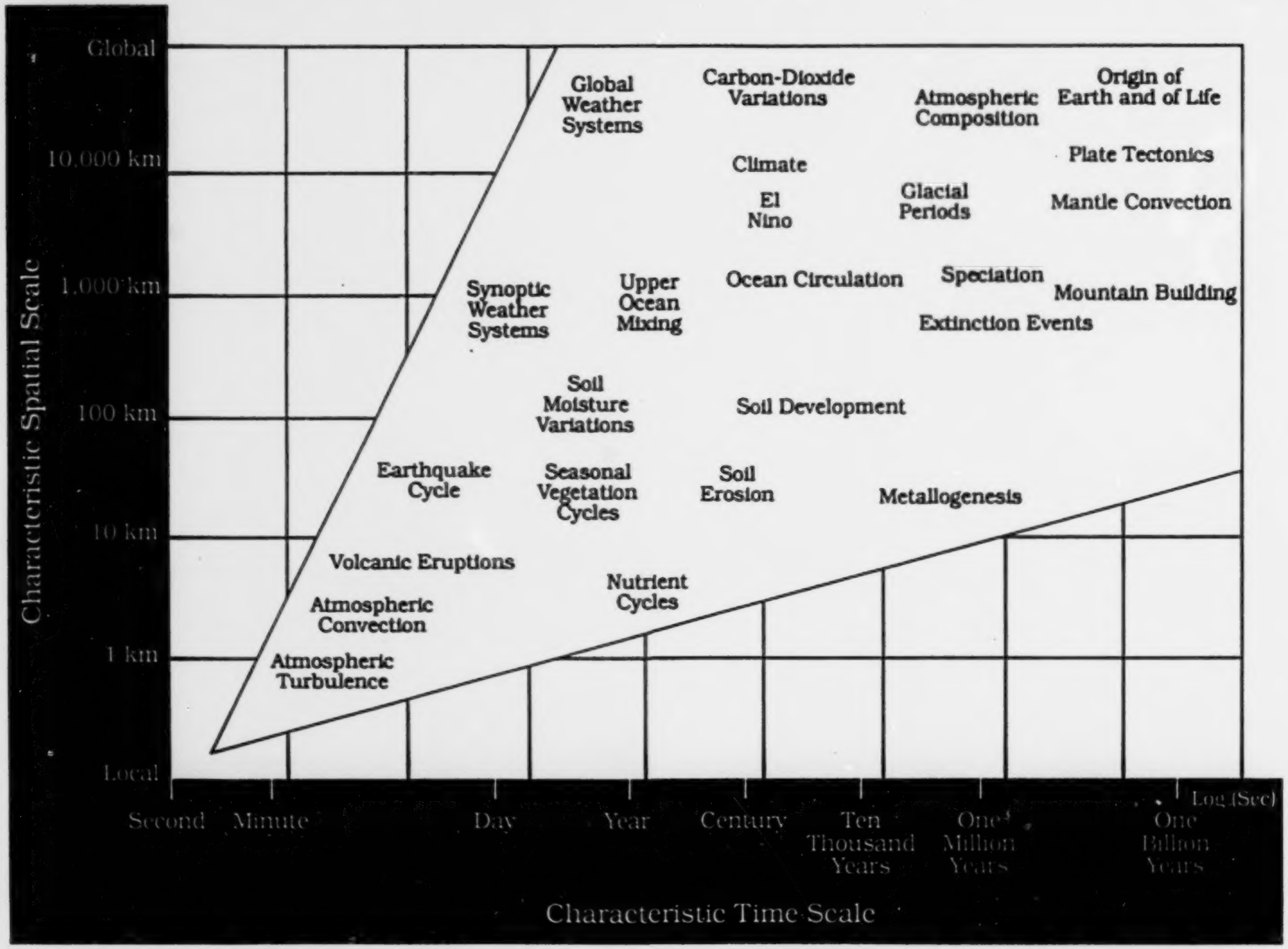
EARTH SYSTEM PROCESSES: Characteristic scales of space and time



Source: NASA, *Earth System Science – A Closer View*, 1988.

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Activities for the Changing Earth System

CONTENTS

MIDDLE SCHOOL

Observing (Bio)diversity 01
Biodiversity Around the School 07
Trees on the Move: Maple Migration 20
Have to have a Habitat 29
In Focus: Endangered and Threatened Species 40
How High's the Water ? 45
Freshwater for a Warmer World 50
The Ozone Hole: Public Response to a Global Threat 68
The Global Climate Game 82

HIGH SCHOOL

Ice Cores - A Key to Unlocking Earth's Climatic Past 117
Volcanic Eruptions and Global Climate Change........ 137
How Have All the Species Gone 148
It Just Keeps on Growing and Growing... 158
Tropical Deforestation: Causes, Effects, and Implications 176
Downeaster Alexa: A Fishery Story 192
Is Sea Level Rising? Well, it Depends... 209
How do Greenhouse Gases affect Heat Absorption 222
How Much is the Global Energy Budget 230
The Goldilocks Problem 240
Global Warming: How Good is the Evidence? 257

Global Change Fact Sheets 270
References for Global Change 291

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MIDDLE SCHOOL ACTIVITIES

12

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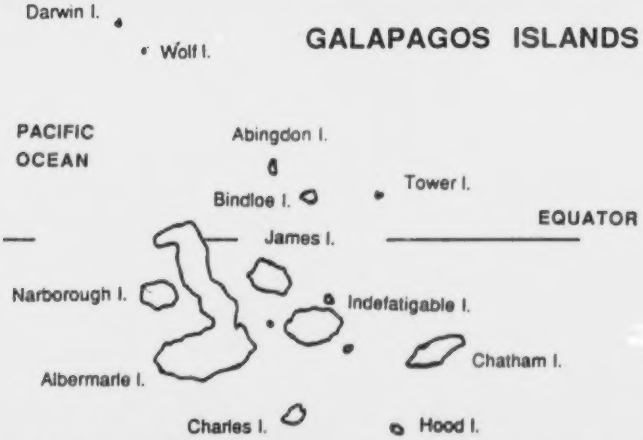
Observing (Bio)Diversity


Darwin I.
Wolf I.
GALAPAGOS ISLANDS
PACIFIC OCEAN
Abingdon I.
Tower I.
Bindloe I.
EQUATOR
James I.
Narborough I.
Indefatigable I.
Chatham I.
Albermarle I.
Charles I.
Hood I.

Scientists need to make detailed, accurate observations in order to correctly interpret what they are seeing. Small outward differences between organisms, for instance, can indicate important but unobservable differences within.

One of the first persons to study these differences was Charles Darwin. In 1835 he visited the Galapagos Islands, which are a small group of volcanic islands located several hundred miles west of Ecuador in the Pacific Ocean. While on the islands he made a collection of plant and animal specimens and noted the small differences between organisms. At first he didn't notice that these variations were specific to the different islands. After his return home to England, he made detailed sketches of the animals including finches (Figure 1). Only then, did Darwin go back to all the Galapagos specimens and note the geographic relationships of their physical differences.

Apparently the finches adapted to the various food sources available to them on the different islands. In this way, the different finch species did not compete with each other for food, their beaks allowed them to feed on a variety of food sources. This, and other evidence, lead Darwin to formulate his ***theory of natural selection.***

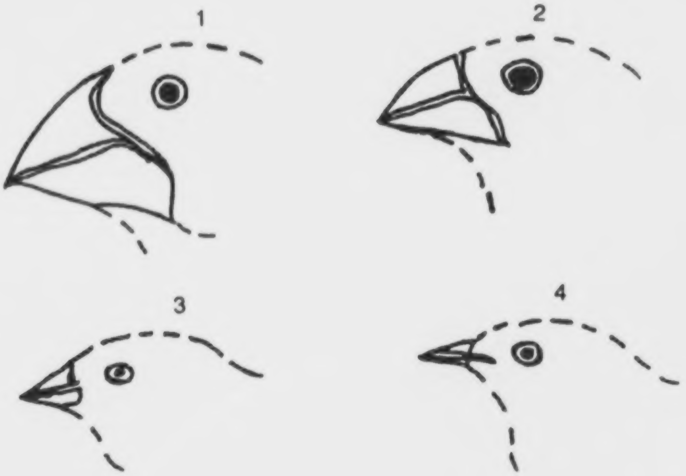


Figure 1. - Galapagos finches showing 4 different beak sizes and types.

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Darwin's theory states that an individual with a physical change, has an adaptive advantage over his/her siblings. This individual may exploit a certain environment, while his/her siblings have to remain in their original environment. This characteristic is then passed on to his/her offspring and over a considerable period of time a new species may emerge, related to the original but clearly distinct from it.

When we look at the impacts of human-caused changes in environments, we observe the variety among living things and note the value we attach to various species. Developing acute skills of observation will prepare us to detect important aspects of our environment and how they change and interact. The concepts studied in this activity include: *natural selection, species, reproductive isolation, evolution, invasion of new species and endangered species.*

Objectives: When you have finished this activity you will be able to:

1) demonstrate an ability to observe small differences between common items.
2) show how items can be classified on the basis of small differences.
3) state how scientists decide whether a group of organisms constitutes a species.

Earth Systems Understandings (ESUs): This activity focuses on ESUs 4 and 5, however the following ESUs are covered in the Extensions — 1, 2, 3, 6 and 7. Refer to the Framework for ESE for a full explanation of each ESU.

Materials: twenty (20) aluminum pull-tabs per team of 2-3 students; at least one pull-tab that separates from the can rather than staying attached to it; paper and pencil for drawing.

Procedure:

1) Test your powers of observation by drawing a familiar object in your classroom from memory. Do not look at it. Compare your drawing with the real thing. What important characteristics did you leave out, if any? What parts did you draw differently than the real thing? Why do you think these differences appeared in your work?

2) Now draw an aluminum pull-tab of the kind that would be attached to a beverage can. Compare your drawing with those of your classmates. Have you all noted the same characteristics of pull-tabs? Do all pull- tabs look alike, or were you remembering different types as you made your drawing?

3) Each team of two or three students will receive about twenty pull-tabs from different brands of beverages. Study the characteristics of the pull-tabs as if they were organisms. For this activity, these pull-tabs are called "*aluminontos*"; "*onto*" means a being, something alive, and imagine that they are actual organisms. Identify the dorsal and ventral sides. Which end would you consider is the head? How accurate were the drawings in comparison to the real thing?

4) Sort the *aluminontos* into groups that have similar characteristics. How do the *aluminontos* differ from each other? What differences are great enough to be used as a means of grouping? How did you decide?

Biologists identify a group of organisms as a separate ***species*** if members of the group can only reproduce successfully among themselves, not with other organisms outside the group. That is, the group is ***reproductively isolated*** from other similar groups. Horses look like zebras but are of a different species, and there are no hybrids between them even though they are of the same genus. Horses (*Equus caballus*) can reproduce with horses, and zebras (*Equus zebra*) with zebras only. On the other hand, under natural conditions all the dogs we have as house pets can theoretically reproduce with each other even though they are very different in external characteristics. They are all of the same species, *Canis familiaris*.

5) At least one team has an *aluminonto* that doesn't fit well into any of the other established groups. Find that "organism" and discuss why it is unique. Since there is only one, how would you as a scientist decide if this is a mutant of the more common species, an invading organism, or an endangered species? Discuss the implications of each possibility. What role would natural selection play in this process?

6) Can you relate your findings with the *aluminontos* to Darwin's finches and the other organisms on the Galapagos islands?

Extensions:

1) Life on Planet Earth is beautiful, unique in the solar system and of immense value to the human race, aesthetically and financially. Divide the class into groups of 3 - 4 students. Each group should produce a presentation, in any form (written, song, play, etc.) and in any medium (slide, video, demonstration, etc.) which exhibits the great diversity of life on the planet. Groups may select one theme, e.g. forests of the world or local ecosystems.

2) Describe how humans' increasing use of technology has affected the diversity of life. Select one group of plants or animals and discuss how it has been influenced by technology.

3) Planet Earth appears to be the only planet in our solar system that sustains life, as we know it. Why? (There are some scientists who believe that there is a chance of microorganisms on Mars.) Why does Earth possess such a diversity of life? How does this biodiversity affect our daily lives?

4) Are all the plants and animals that have appeared over millions of years of development still present on the planet? Are dinosaurs, huge treeferns and passenger pigeons still living? Why not? Give reasons for your answers.

5) If Charles Darwin was alive at present, what type of career would he have? What type of training would he require to do his work? What other careers are

involved in evolution and investigating the planet's past?

6) Are there present examples of organisms that are adapting to changes in their environment? Are these changes artificial or natural or both? What role do the evolving subsystems play in these adaptations? Give reasons for your answers.

Teacher Background Information:

Lewin, R. 1978. *Darwin's Forgotten World.* New York: Gallery Books.
This book contains numerous photographs sharing the diversity of life in the Galapagos archipelago. It also summarizes Darwin's life and the Voyage of the Beagle. Easy reading. (Maps and illustrations used in this activity are from this book.)

Wilson, E. O. 1992. "The Diversity of Life." *Discover.* September. 45 - 68.
An excellent article summarizing this scientist's thoughts on the present situation of biodiversity and the planet in general. Wilson examines various extinctions throughout the history of Earth and how different species evolved. He compares this with the present rate of species extinction. This article is a more readable account of the material appearing in the 1988 book *Biodiversity* edited by this author.

Findley, R. 1990. "Will We Save Our Own?" *National Geographic.* 178 (3) : 106 - 136.
An article examining the situation of the virgin, old-growth forests of the U.S. Findley documents the history of logging in this nation and how the Forest Service has managed various forests. The various people connected with forest management are mentioned in the article. The questions of deforestation and the loss of biodiversity in these store houses of life are investigated. Illuminating illustrations and photographs create vivid images of this ecosystem and its problems.

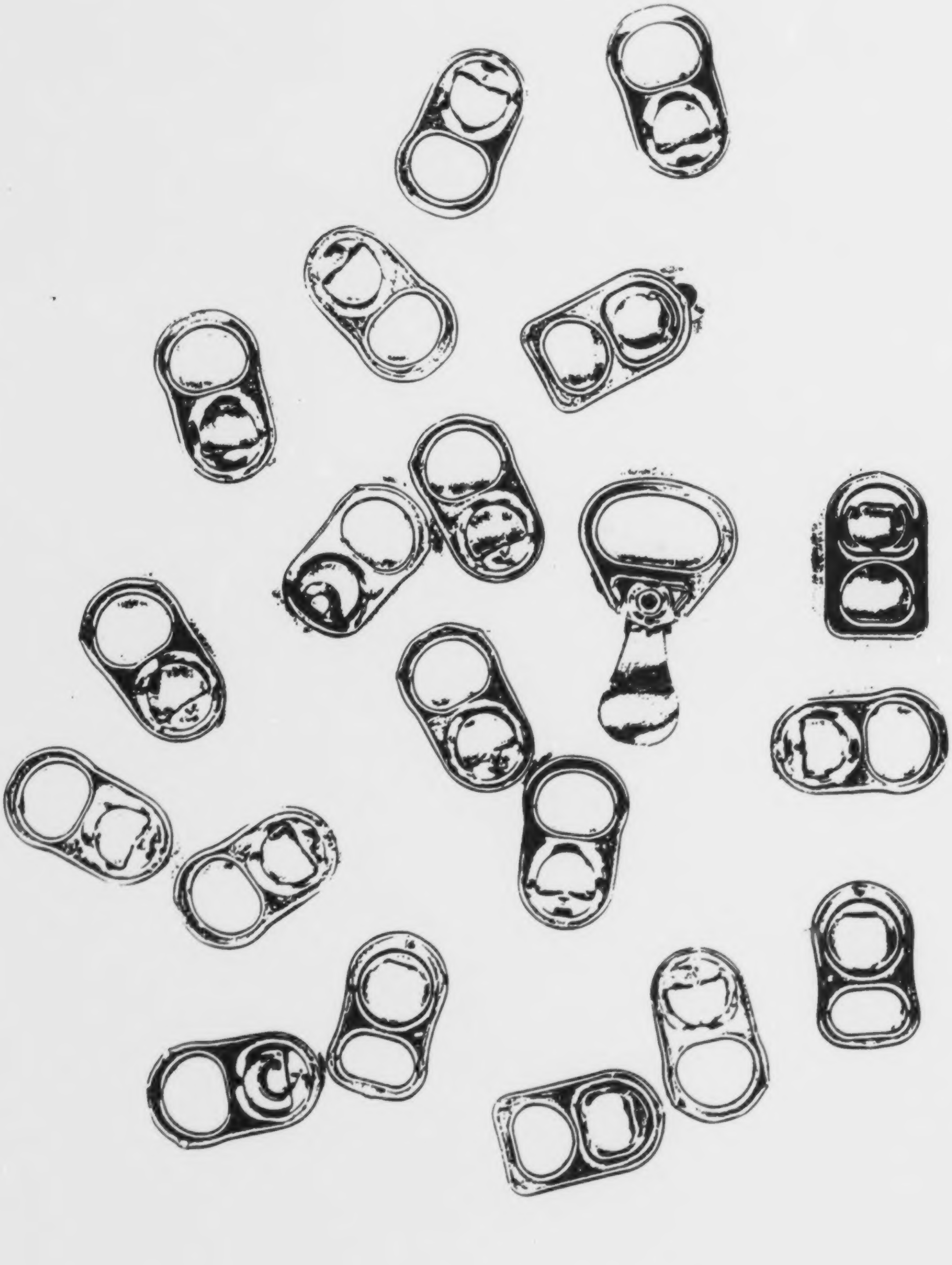
References:

Hageman, S. J. 1989. "Use of aluminontos to introduce general paleontologic and biostratigraphic principles." *Journal of Geological Education.* 37 (2) : 110 - 113.

VIDEO

Sagan, C. 1980. Cosmos — A Personal Voyage: One Voice in the Cosmos Fugue. KCET and Carl Sagan Productions Inc. In Association with BBC and Polytel International. © 1980 Community TV of South California TV of KCET.
In this video, Sagan condenses the evolution of the planet and life into a cosmic calendar year and speculates on the occurrence and form of organisms on Jupiter.

TG1. A community of *aluminontos*. Mark each individual to tell if its dorsal (top) view is showing, or its ventral side (underside). What characteristics indicate that more than one species may be present?



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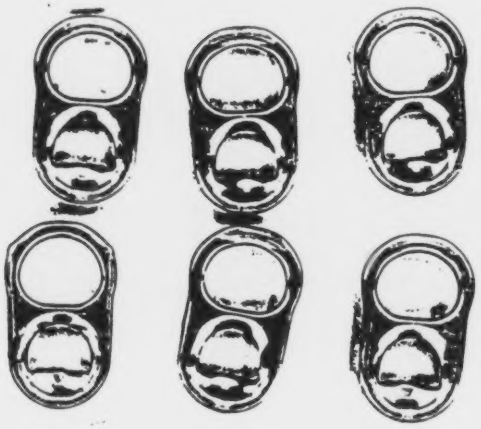
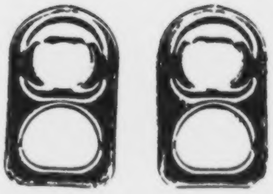
TG2. A possible classification scheme for *aluminontos*.

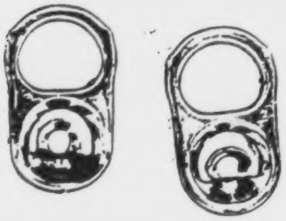
Species 1



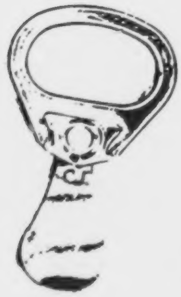
Species 2



Species 3



Endangered Species



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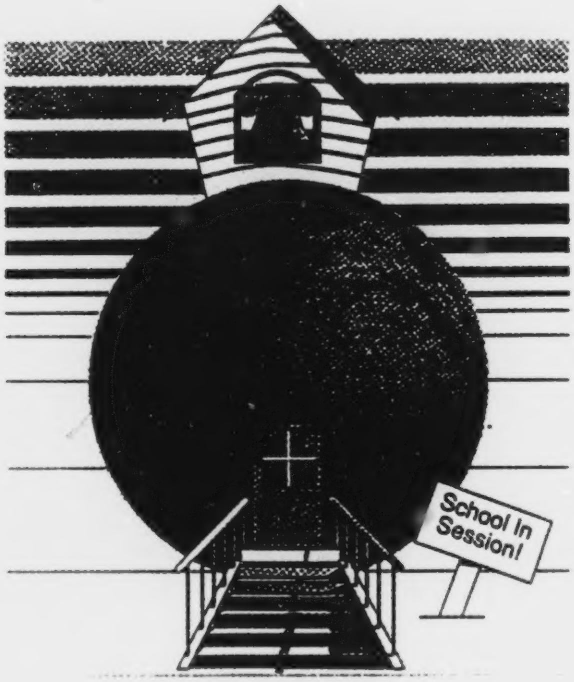
School In Session!

illustration by C. Havel

Biological Diversity Around the School

You don't have to be in a tropical rain forest to observe biological diversity. Wherever there is more than one species present, there is diversity. In this activity students will examine their own surroundings for the amount of biological diversity present. The concepts studied include: *biodiversity; classification systems; stable ecosystems and species.*

Direct observations and simple tools can be used to create, test, and modify the theories that represent and explain changes in the Earth system. The backyard of a school is a natural setting for students to begin their observations. It is not always necessary to have the latest computer technology. The human senses, in a local setting, can be used to begin this crucial process of inquiry.

Objectives: When you have finished this activity you will be able to:

1) describe two or more different habitats near your school.
2) identify several different organisms in each habitat.
3) demonstrate an ability to use taxonomic keys to classify organisms.
4) calculate a species diversity index for the habitats identified.

Earth Systems Understandings (ESU): This activity focuses on ESUs 1, 3 and 4, however the following ESUs are covered in the Extensions — 2, 5, 6 and 7. Refer to the Framework for ESE for a full explanation of each ESU.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

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Materials: air thermometer; soil thermometer; psychrometer (used for measuring humidity); light meter; soil testing kit (optional); clipboard; data sheets; pencil; guide books (see pages 18 — 19 for a suggested list of guides); computer with database software; Figures 1 and 2; biome map.

Procedure:

1) In teams of four students, go outside the school to an area with several different habitats available. Your teacher will identify the size of habitat to be studied based on available areas.

> [Ideally each area will be a square about 3 m on each side.]

Each team will have one person assigned to each of the following responsibilities:

a) physical characteristics measurement and recording;
b) organism identification using taxonomic keys;
c) organism sketches as needed, and written overview description of general characteristics of the area;
d) organism counts by species.

> [It is likely that organism identification will be the most difficult job. Other students without this assigned responsibility should be enlisted to assist in identification if needed. You may wish to have all students participate in #2-3 below, then divide the identification responsibilities.]

2) In the habitat assigned to your team, record on a single team data sheet the physical characteristics of the area:

i) air temperature one centimeter and one meter above the ground;
ii) soil temperature on the surface and eight centimeters in the ground;
iii) amount of light reaching the ground and one meter above the ground;
iv) soil moisture, pH, and compaction (if equipment is available), and relative humidity of the area.

3) Write a brief paragraph describing the general type and amount of plant growth in the area, and record any signs of animals there.

4) Using field guides or locally constructed taxonomic keys, identify in the area as many species as possible, both plants and animals, by common and scientific names. Take care not to disrupt the habitat and organisms as you work in the area. Count and record the number of individuals in each species. If you cannot identify an organism, sketch it and check other reference materials in the library. It is important to accurately determine the number of different species in the area, even if all cannot be identified precisely.

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5) Indoors, enter your species into a computer database. Each data file should have a format that includes the following:

Phylum
Subphylum
Class
Order
Family
Genus
Species

Common name
Number of individuals
Habitat (Team assignment)

Complete as many of the database categories as possible for the organisms you find.

6) Arrange your data in a way that makes it valuable to you: most abundant to least, alphabetically by common name, all plants, then all animals, or however you can use the data efficiently.

7) Calculate the **species diversity index** for the habitat you were assigned, using the following formula.

$$d = S / \log A$$

d = diversity

S = number of species in the sample

A = the sample area, usually in square meters

[for younger students, using $d = S/A$ also gives adequate comparisons of data]

8) Compare the data you collected, and the calculations you made, with those of other teams observing different habitats. What types of plants appear to grow best in habitats that are moist and cool? warm and bright? Which habitats have the greatest number of individual plants? Which have the smallest number of plants? Compare the size of the numerous plants with the size of the scarce ones. Which habitats have the most signs of animals?

9) Scientists know that the most naturally **stable ecosystems** are those that have a high biological diversity. Considering the importance of interrelationships, food webs, and such, explain why this is the case.

[Stable ecosystems have attained a high level of biodiversity with complex interrelationships and food webs. This usually is indicated by the establishment of the climax community for that ecosystem. For instance, while a forest community is forming it will have different types of plants and animals present at various stages in its development. As the forest matures, some of these plants may die off; others will colonize the area. Animals show a similar

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pattern. The highest diversity seems to appear before the community has reached the climax stage in succession. However, once the forest has attained maturity and become a stable ecosystem, a high diversity of plants and animals will exist.]

10) On your data sheet, list the species diversity calculated by all teams in order from the highest to lowest diversity. Which school habitat is likely to be the most stable?

11) Figures 1 and 2 are photographs of the city of Worthington, situated approximately 8 miles outside Columbus, Ohio. The first photograph was taken in 1938, the second in 1989. The circular dot on each photograph represents the same geographic location. The dot is located at the junction of the two roads, right of center in Figure 1. In Figure 2, the dot is positioned right of center, towards the lower right corner of the photograph.

What has happened to the area over this 51 year period? How has the area changed? From what you can see, how has the human community and its lifestyle altered during this period? Do you think this development has had an effect on the biodiversity of the area? Why?

The DNR of your state can help you locate recent and old aerial photographs of your area so you can make similar comparisons.

12) Examine the biome map. Describe the percentage of the world that has similar ecosystems to your local ecosystem. Discuss a larger ecosystem (beyond your school) that would have a very high or low biological diversity.

13) Which is the most stable ecosystem — a tropical forest or a desert? Why? Why have deserts existed for so long?

[Further discussion could continue on this aspect of stability and perhaps the need to alter the definition of this term.]

14) How does what you have learned in the previous activity, 'Observing (Bio)Diversity,' relate to this activity? From information concerning the Galapagos Islands, would you consider them stable ecosystems? Why?

15) You have examined a biome map and photographs of localized development. Humans, as a species, are increasing in number worldwide. What influence do you think this increase in numbers and the development associated with it will have on the biomes of the world? What do you think should be done? How could you help this situation?

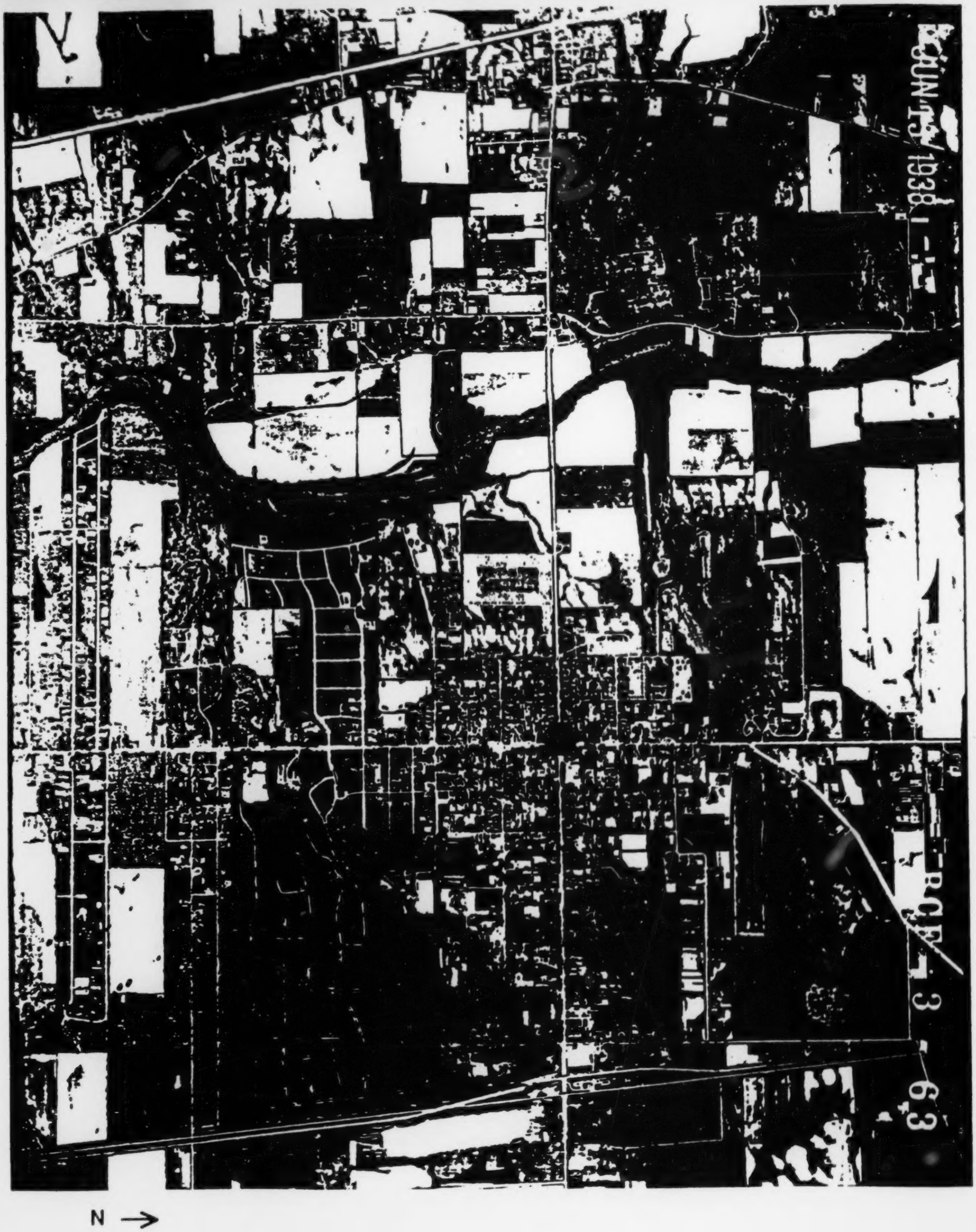
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Figure 1. - A photograph of the city of Worthington taken in 1938. Locate dot on photograph.

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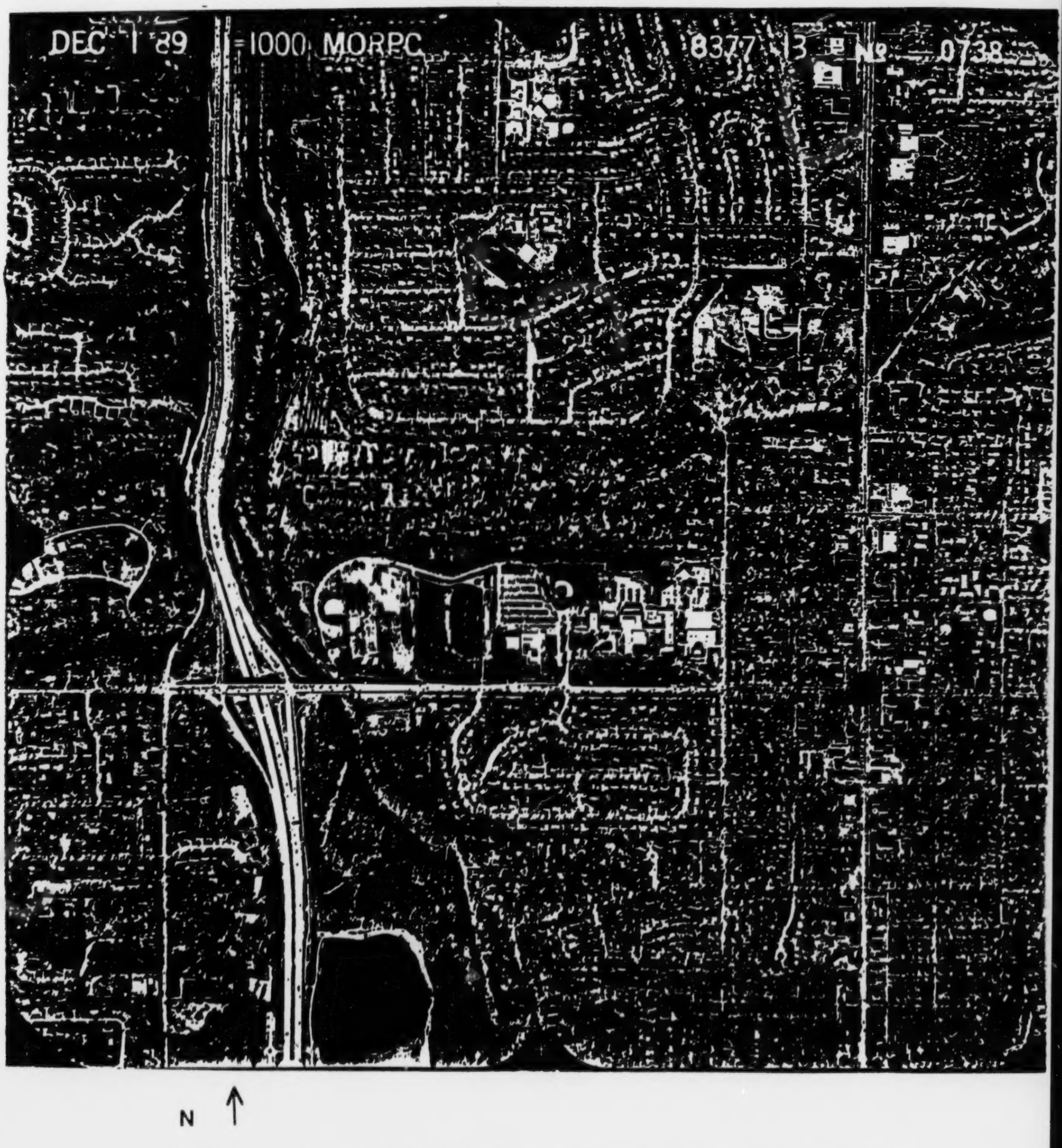
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Figure 2. - A photograph of the city of Worthington taken in 1989. Locate dot on photograph.

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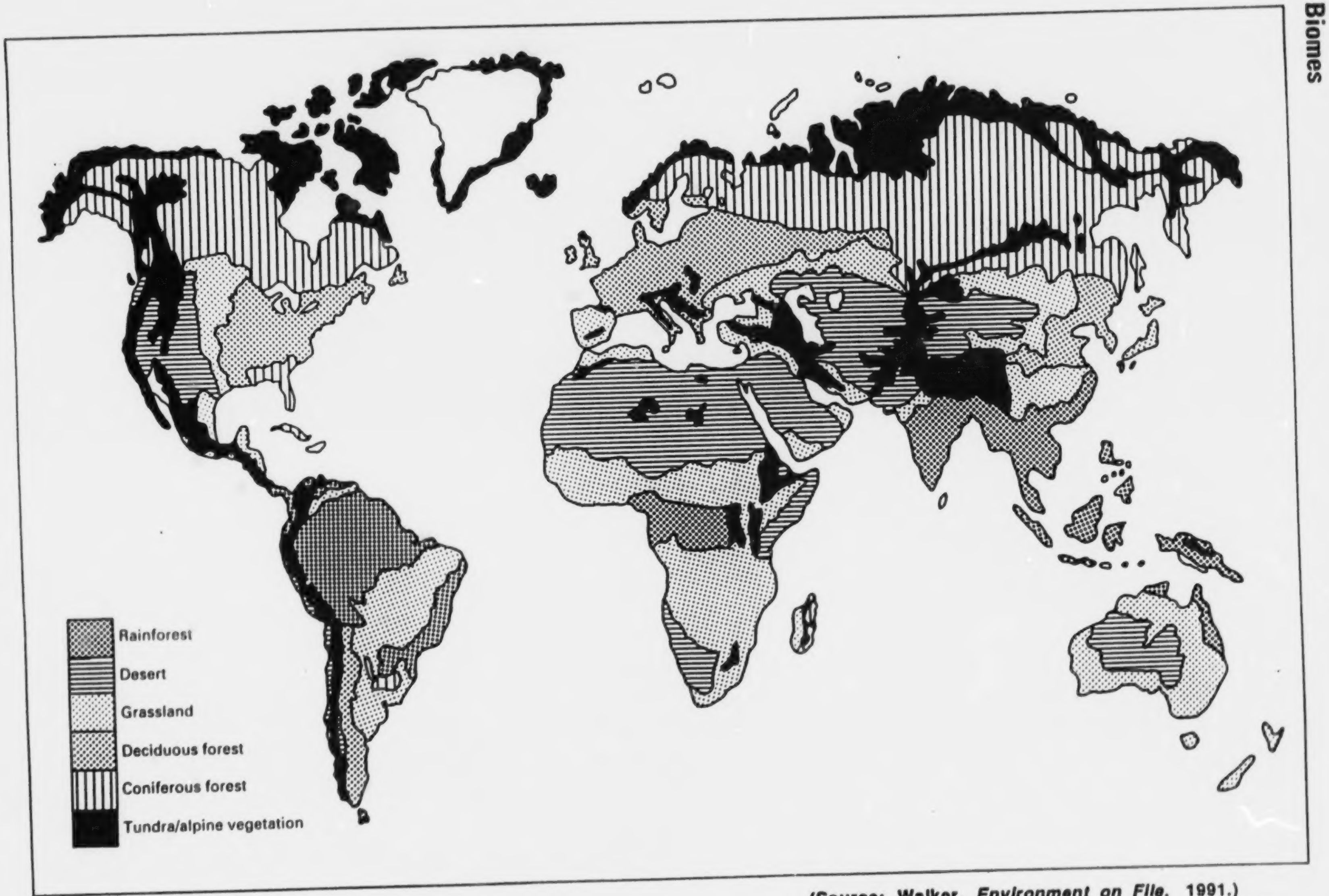
Biomes


Rainforest
Desert
Grassland
Deciduous forest
Coniferous forest
Tundra/alpine vegetation

©DIAGRAM

(Source: Walker, *Environment on File*, 1991.)

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SCHOOL BIODIVERSITY DATA SHEET

TEAM

HABITAT
LOCATION

1 Team Task Assignments:

HABITAT DESCRIPTION

2 **Physical Characteristics:**

Air Temp. 1 cm 1 m

Soil Temp. Surface 8 cm deep

Light Ground 1 m

Relative Humidity

3 **Soil Characteristics**:

4 **Appearance of the area:**

5 **Biological Characteristics:**

SPECIES	NUMBER	SPECIES	NUMBER

SCHOOL BIODIVERSITY DATA SHEET (II)

6 Put the number of species in a database and arrange them. Attach a printout from your work.

7 Calculate the species diversity index for your habitat.

COMPARISON OF HABITATS:

8 Compare the data of all habitats studied. What types of plants appear to grow best in habitats that are:

moist and cool?

warm and bright?

Which habitats have the most individual plants?

Which have the least plants?

Compare the size of the numerous plants with the size of less common species.

Which habitat had the most animal signs? Why?

9 Explain why high biological diversity indicates a stable ecosystem.

10 List the class diversity indices from the highest to the lowest. Which school habitat is likely to be most stable?

11 Describe a larger ecosystem that would have a very low/high biodiversity.

Extensions:

1) You have just examined the biodiversity that exists around your school. The habitat around your school is a modified habitat. Explain how you think this alteration has changed the flora and fauna in this area. If your school had not been constructed in this location, what type of habitat do you think would have been present?

Some students should produce a collage poster presentation for the area before the school and other structures existed there, while the remainder of the class should produce a similar presentation for the current situation. Students should give reasons why they believe or don't believe that the area around the school is unique, beautiful and of great value.

2) How have the different subsystems interacted to create the areas that surround you in school and at home? Are these interactions continuing or have they ceased? Support your answer with some scientific evidence.

3) Examine the age of the planet Earth and its evolving subsystems. How has this process influenced the diversity of life on the planet? Humans have been present on Earth a very short time in relation to the age of the planet. How have humans influenced and reshaped the landscapes? Examine this question throughout human development — from prehistory to the industrial revolution and up to the present day. What Earth evolution processes are affecting the area around your school and home? Explain your answer.

4) An alien ship has landed near your school. They inform you that they are going to destroy the planet Earth, because it is blocking the construction of an interstellar highway. You have to produce an environmental impact study to dissuade the aliens from terminating the planet.

5) As a continuation of the previous question, assume a local development is taking place which needs an environmental impact study produced. Some of the students should produce this study. A simulated town meeting should be created in which both sides are examined. The students not involved in producing the study should roleplay the developers and give reasons for the development.

6) List the people that may affect the biodiversity around your school. In what ways could the training for their career make them more aware of the effects that they may have on biodiversity in general.

7) Two Viking space craft landed on Mars in an attempt to identify the presence of life there. Why do scientists think that Mars might harbor life? What did the space craft find? How were experiments designed to identify life on Mars? If life occurs there, what could be said about its diversity?

Teacher Background Information:

Revelle, P., and Revelle, C. 1984. *THE ENVIRONMENT Issues and Choices for Society.* Boston: Willard Grant Press.
A textbook that uses an environmental approach for the dissemination of knowledge concerning the problems that face the environment. Issues covered include energy problems, population increases, ozone depletion, habitat loss, etc. The authors also examine the decision-making process in relation to environmental problems.

National Park Service. 1991. *Biological Diversity: It makes all the difference.*
An excellent 14 minute video that examines biodiversity at species, genetic and ecosystem levels. It also investigates biodiversity in relation to ecology, economy, ethics and esthetics. (NPS units possess this video with a set of interpretive curricula. Contact your local NPS unit for details of this video.)

Wilson, E. O. and Peter, F. M. Editors. 1988. *Biodiversity.* Washington D.C.: National Academy Press.
A collection of essays by eminent scientists that detail the current situation of biodiversity in the world. They examine various facets of this issue including the loss of biodiversity, its results on the environment and our economic dependence on biodiversity.

References:

BSCS. 1982. *BIOLOGICAL SCIENCE An Ecological Approach. BSCS Green Version.* Boston: Houghton Mifflin Company.

NASA. 1987. *Photography Index.* Washington D.C.: Public Affairs Division, D.C. 20546.

Spitzer, C. R. 1980. NASA, Scientific and Technical Information Branch. *Viking Orbiter Views of Mars by the Viking Orbiter Imaging Team.* Washington D.C.: U.S. Government Printing Office, D.C. 20402.

Walker, R. 1991. *Environment on File.* New York: Facts on File, Inc.

Whittaker, R. H. 1975. *Communities and Ecosystems.* New York: MacMillian Publishing Co., Inc.

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GUIDE BOOKS

The following is a list of guides that you might like to use for your identification and drawing activity. It is best to avoid books that have a worldwide scope. There are U.S. guides, regional guides and state guides.

Avoid the temptation to just draw pictures from the guidebooks. You should really look for your local species and learn how to identify and appreciate them.

Series

1) **Peterson Field Guide Series,** Houghton Mifflin Co., Boston, Massachusetts.
    - — black and white illustrations
    - — some regional guides
    - — some topics include: mammals, wildflowers, seashores, fishes, insects, reptiles and amphibians, birds and birds' nests, trees and shrubs, forests.

2) **Golden Field Guide Series,** Western Publishing Co., Racine, Wisconsin.
    - — two series, one smaller, simple pocket guide and a more complete one
    - — topics include: seashells, fishes, reptiles and amphibians, weeds, flowers, insects, birds, mammals, trees.

3) **Simon and Schuster Guides,** Simon and Schuster, New York.
    - — color illustrations
    - — topics include: fossils, shells, trees, insects, mammals, mushrooms, cacti and succulents, freshwater fish.

4) **Stokes Nature Guides,** Little, Brown and Co., Boston, Massachusetts.
    - — black and white illustrations
    - — topics include: wildflowers, animal tracking, nature in Winter.

5) **Audubon Society Field Guide Series,** Alfred A. Knopf Co., New York.
    - — color photographs
    - — some regional guides
    - — topics include: fossils, seashores, fishes and marine mammals, wetlands, deserts, wildflowers, trees, insects and spiders, birds, mammals, forests.

General

1) *A Field Guide to The Familiar: Learning to Observe the Natural World.* 1984.
Lawrence, G. New Jersey: Prentice-Hall, Englewood Cliffs.

2) *Tom Brown's Field Guide to Nature Observation and Tracking.* 1983.
Brown, T. Jr. New York: Berkley Books.

3) *Crinkleroot's Guide to Walking in Wild Places.* 1990. Arnosky, J.
New York: Bradbury Press.

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4) *Lions and Tigers and Bears: A Guide to Zoological Parks, Visitor Farms, Nature Centers, and Marine Life Displays.* 1984. Ulmer, J. New York: Garland Publishers.

5) *World Wildlife Fund's Guide to Endangered Species of North America.* 1990. Edited by Lowe, D. W. Washington D. C.: Beacham Publications.

Flora

1) *Common Poisonous Plants and Mushrooms in N. America.* 1991. Edited by Turner, N. J., and Szczawinski, A. F. Timbress Press.

2) *Mushrooms Demystified: A Comprehensive Guide to the Fleshy Fungi.* 1986. Arora, D. Ten Speed Press (Second Edition.)

3) *Wildflowers and Weeds, A Field Guide in Full Color.* 1972. Courtenay, B., and Zimmerman, J. H. New York: V. N. Reinhold.

4) *Grasses, An Identification Guide.* 1979. Brown, L. Boston, Massachusetts: Houghton Mifflin Co.. (Line drawings.)

5) *North American Trees.* 1980. Preston, R. J. Ames, Iowa: Iowa State University Press. (Exclusive of Mexico and the tropical U.S..)

Fauna

1) *Insects of North America.* 1971. Klots, A., and Klots, E. New York: Doubleday & Co..

2) *Butterflies East of the Great Plains.* 1984. Opler, P. A., and Krizek, G. O. Baltimore, Maryland: Johns Hopkins University. (Color photographs.)

3) *Field Guide to the Birds of North America.* 1983. Allen, T. B. Edited by Scott, S. L. National Geographic Society. (Color photographs.)

4) *Ducks at a distance: A Waterfowl Identification Guide.* 1978. Hines, B. Washington D. C.: Department of the Interior, Fish and Wildlife Service, U. S. Government Printing Office.

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Trees on the Move:

Maple Migration

When we think about changing climates and their impact on biological diversity, we most often think of animals as the types of organisms that are threatened. But plants too will encounter climate changes and have to adapt or perish. Where the vegetation consists of crops that people plant, we can expect that people will just try to plant them elsewhere or find a better crop for the new climate. With forest vegetation, it's a different story. Trees can't migrate very rapidly to the places where climate is favorable! In past ice ages, the changes in climate were slow and some evergreen tree species were able to migrate south in front of the glaciers as they advanced. The climate changes we face in global warming are likely to occur much faster than that, and trees may not be able to "make their move" in time to survive.

This activity focuses on the sugar maple as a species that will be affected by climate changes. Maples are already impacted by acid deposition, especially in the northern parts of their range in Canada. The sugar maple is the most important of the maples. It may reach a height of 135 feet (41 meters) and have a trunk diameter of 5 feet (1.5 meters). It has gray bark and dark green leaves. In autumn the leaves turn to beautiful yellow, orange and red. In addition to the maple syrup we get from these trees, the wood of the sugar maple is prized because it is heavy, hard and takes a fine polish. The wood has been used since colonial times for furniture, flooring, musical instruments, and saddles. It makes a good fuel wood because it is dense and burns hot for a long time.

The sugar maple leaf is the national emblem of Canada because of the tree's importance to the Canadian economy. Eastern Canadian forests contribute $14 billion to the nation's economy and maple syrup production adds another $36 million. The leaf forms the centerpiece of the Canadian flag (Figure 1).

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

In this activity we will examine the climate niche of the sugar maple *Acer saccharum*, and see how some global climate models predict that niche is likely to change. We will observe an example of how plants migrate, and predict some possible impacts on North American economy as maple ranges shift.

Figure 1. - Canadian Flag with Sugar Maple symbol.

The concepts studied in these activities include: *climate; plant migration in relation to changing climate; General Circulation Models (GCMs) ; isotherm maps; impact of plant migration on economies; and the factors necessary for plant migration.*

Objectives: When you have completed this activity you should be able to:

1) compare temperature and precipitation predictions made by General Circulation Models (Activity A).
2) distinguish differences between range maps for a given tree species (Activity A).
3) explain how plants "migrate" (Activity B).
4) analyze how impacts of global change on plant species would have a human impact as well (Activity B).

Earth Systems Understandings (ESUs): This activity concentrates on ESUs 2, 3 and 4, however, the following ESUs are covered in the Extensions — 1, 5 and 7. Refer to the Framework for ESE for a full description of each understanding.

Activity A: How will global climate change affect the habitat for maple trees?

Climate is the general character of the weather that exists over a particular region of the earth for a long period of time. Unlike the weather, which represents hour-to-hour and day-to-day changes in the atmosphere over a region, climate is the average of all the weather changes over a region for a great many years.

The major factors that are often used to characterize the climate of a region are temperature and precipitation. Because the surface of the earth is not heated evenly, and because land masses, oceans, and polar ice masses are distributed unevenly over the surface of the earth, the climate varies greatly from region to region.

One way climatic conditions can be summarized is by constructing an isotherm map. Isotherms connect all the places of equal average temperatures for that region. Figure 2 is a January isotherm map for North America. Predict how global climate change could impact the position of the isotherm lines on a future January map?

Isotherm -

Isothermal lines on a map connect places that have the same average temperature. The map at the right shows the January isotherms for most of North America. Temperature is measured in degrees. Average temperatures shown on the map range from -40°C to +20°C.

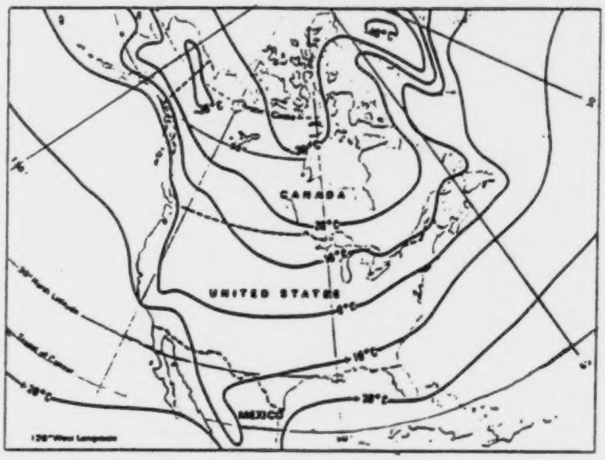


Figure 2. - Isotherm map for North America.

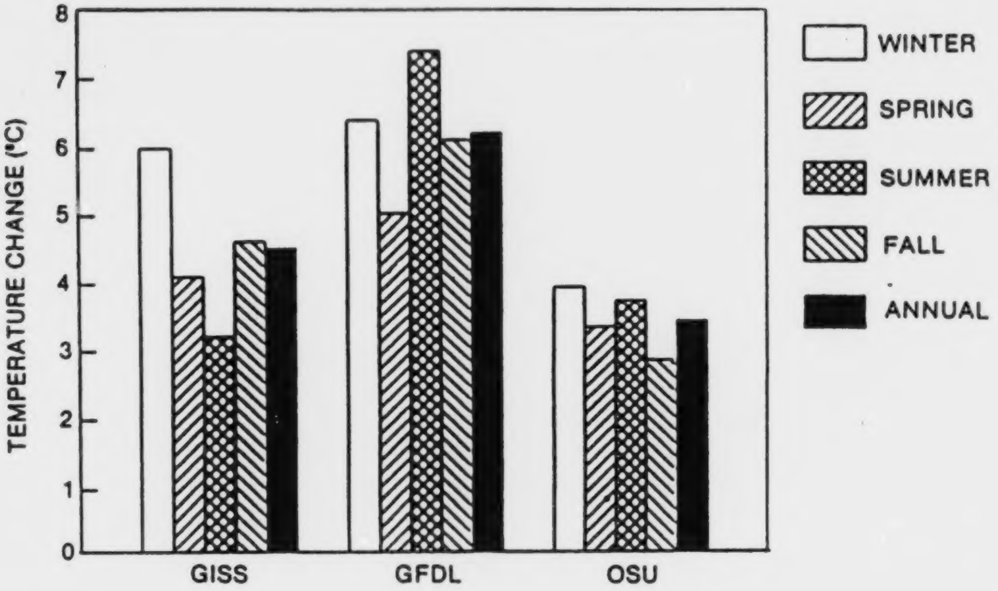
Scientists have been trying to understand climate by studying current records of events and by examining the geologic records. The importance of understanding and predicting future climates has intensified as the amount of carbon dioxide in the atmosphere has increased. Since there are so many physical processes responsible for the structure and variation of climate, scientists have constructed mathematical models to project future climates.

Computer models can help illustrate events that may occur in the future. Scenarios may be used to identify possible effects of climate change and to evaluate responses to those effects. By analyzing many scenarios, scientists may be able to determine the direction and relative size of change. It is important to realize that scenarios are not predictions, and their probabilities are not known.

Materials: 'Understanding Climate Models' fact sheet.

Procedure:

The most frequently reported climate predictions are based on General Circulation Models (GCMs) named for their place of origin: GISS (Goddard Institute for Space Studies - NASA), GFDL (Geophysical Fluid Dynamics Laboratory - NOAA), and OSU (Oregon State University). From these models, it is possible to calculate the impact of the doubling of CO_2 on global climate change. For this purpose, North America has been divided into a number of regional grid boxes (or columns of air) approximately 300 miles on each side. The next page illustrates the GCMs for specific points within the grid boxes in the Great Lakes area. For a comparison of these models, see the fact sheet cited in the materials section.



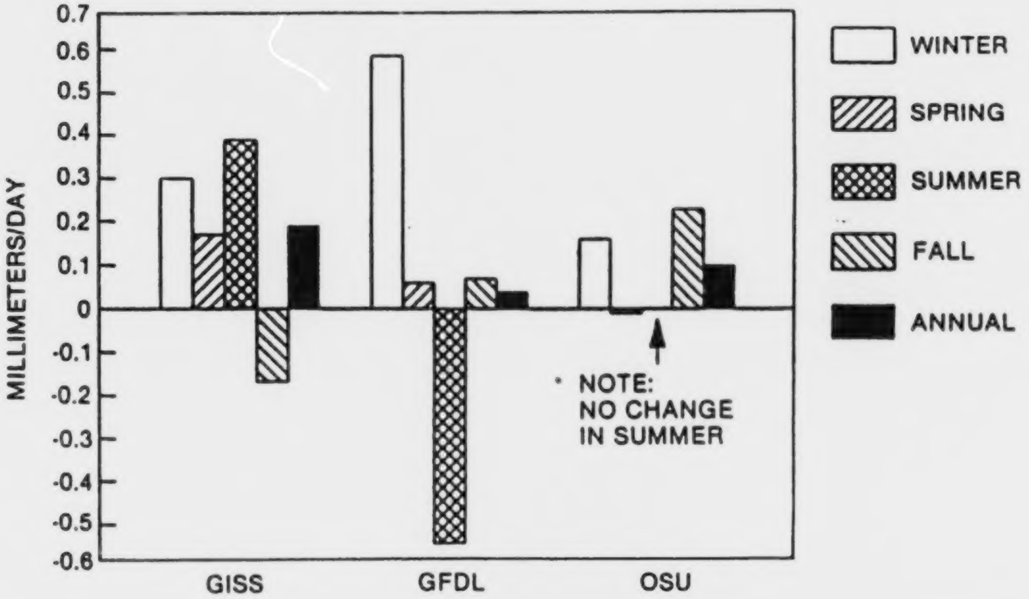


Figure 3. - General Circulation Models (GCMs) illustrating the average change in temperature (upper) and precipitation (lower) over Great Lakes grid points. (Source: US EPA, *The Potential Effects of Global Climate Change on the United States*, 1989.)

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1) Each species has a certain climate niche, the region where temperature and rainfall are optimum for growth. Since the sugar maple covers a large area of North America, several grid points of the major climate models are examined for information about the predicted changes that will result from a doubling of CO_2. In Figure 3, the Great Lakes grid point is examined and predictions of each GCM are shown.

Answer the following questions using Figure 3.

a) Compare the three GCMs on the following:

		GISS	GFDL	OSU
Temperature increase:	Wi			
	Sp			
	Su			
	Au			
Precipitation change	Wi			
	Sp			
	Su			
	Au			

b) Which model predicts the greatest temperature increases over the entire year?

c) Which model predicts the most dramatic seasonal differences in precipitation?

d) Which is the most conservative model - the one that predicts the least change?

e) Discuss the various models and what they mean in terms of overall impact. For instance, what if the extreme summer temperatures of GFDL predictions were actually accompanied by the decrease in rainfall predicted for the same season? Do all models predict summer drought?

2) Describe what happens to sugar maples in each season, and speculate on how the predicted changes of one model might affect the annual cycle of the tree's life.

Season	Normal Characteristic	Climate Impact
Winter	For example: Twigs are dormant, no leaves	Shorter time in dormancy, potential for more annual growth

3) Look at a map of North America showing present climate belts. Where are the predicted temperatures and rainfall patterns of climate models now found on the continent? If these areas are translated northward into the maple region, where will the present maple climate niche probably go?

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4) Check your prediction by comparing it with Figure 4. This projected maple migration was completed in 1989 by two scientists. They studied how climate models could predict responses to CO_2 increases and what this could mean for Great Lakes forests. In Figure 4 they predicted that these areas will be hospitable for sugar maples. Why are the GISS and GFDL ranges different?

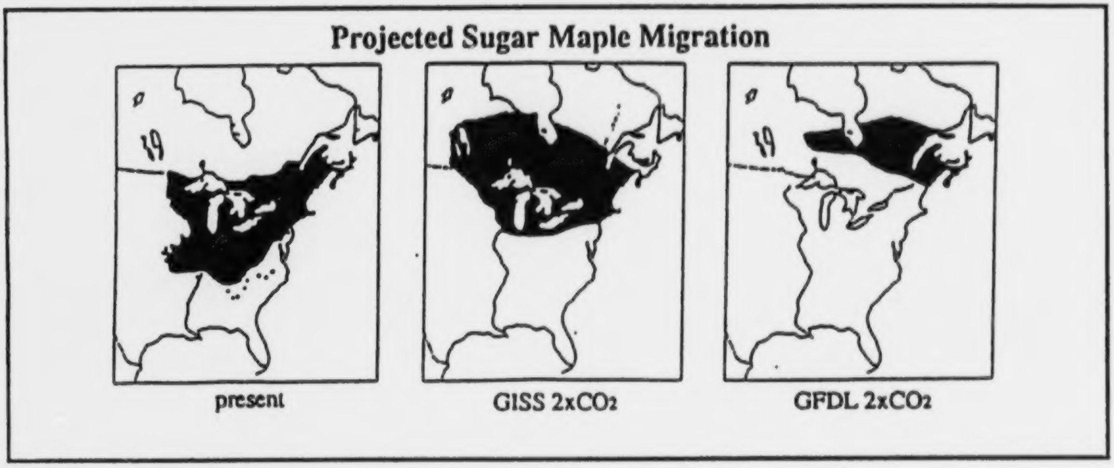

Figure 4. - GCM predictions applied to climate niche of sugar maples. (Source: Zabinski and Davis, *The Potential Effects of Global Climate Change on the United States*, 1989.)

5) From research and books available to you, examine how Canada, the upper Midwest and northeast of the United States depend on maples and other forest species. Develop two scenarios with your team, one for each of the GCM predictions, to analyze how Canada would be helped or harmed if the scenarios became reality. Be creative in your use of information.

6) If people involved in maple syrup production believe that the prediction of climate change for their region is correct, how could they plan for such an event? Is it possible to plant in different areas, such as near the edges of the projected sugar maple migration regions? Give reasons to support your answers.

Activity B: How can trees migrate?

To have a computer draw new boundaries within which the maples can live in the next century is somewhat misleading. The maples are not in all those areas now. How will they get there? This outdoor activity will demonstrate how plants can colonize new areas if those areas are hospitable.

Materials: enough seeds of maple, ash, milkweed or dandelion for each team of 3-4 students to have a handful; one meter stick or tape measure per team; graph paper, anemometer and magnetic compass.

[Samara-type (winged) tree seeds will work best for this activity because they are heavy, fly erratically, and are easy to see when they land. Use the fluffier milkweed or dandelion seeds only if no tree seeds are available.]

Procedure:

1) With your team, stand in a spot marked by your teacher. Measure the wind speed with the anemometer and the wind direction with a magnetic compass. Record these on your worksheet. On your graph paper, place a mark in the center to represent the present-day forest (your team's starting position).

[The teacher should select some starting points near pavement and some near grass or bare soil. Also, put bright marker color on seeds to help find them.]

2) Toss 4-5 seeds high into the air so the wind catches them. Watch where they go. Measure the distance and direction from your starting point to each seed, and plot the seeds' positions on your graph paper. Decide with your team how many squares you will use to represent one meter. You will be tossing seeds at least 4 times.

3) Send one team member to the spot where each seed landed. Have each member toss 3 more seeds and mark their new positions on the graph.

4) For the next toss, each team member will go to the location of a seed that is farthest away from the original "forest." Toss 3 more seeds and mark their positions.

5) Repeat Step 4 once or twice more, then examine your graph with your team.

6) Draw a line on the graph paper that encircles your starting place and all the seeds whose positions you plotted. Describe the area through which your trees migrated: its general shape, direction from the original forest, width and length, any overlap with other teams, etc.

7) What conditions are necessary for seed germination? Did each seed get the same chance to germinate? Why? Did any seeds fall on paved areas or other spots where their chances to grow were very small? If a maple forest were migrating through North America from where it is now, what obstacles might be in its path? Could the obstacles stop the migration? Discuss with your team and class.

8) Summarize how plants might be able to move into the areas that climate models predict as their future range.

Extensions:

1) At the peak of the autumn season in the northeast and midwestern sections of North America, a kaleidoscope of colors appears as a result of the pigment changes in the leaves of deciduous trees, particularly in maple leaves. This is truly one of the more spectacular, colorful events in nature. People travel from all across the nation and from around the world to witness this event, generating considerable business in

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the areas. From the knowledge you have acquired in this activity, suggest how climate change could influence (a) the autumn colors and (b) this tourist industry.

2) The maple syrup industry is a result of the interactions between people and maple trees, and maple trees and their environment. Describe the historical background of maple syruping and how syrup is produced. Discuss the influence of global climate change on the amount of syrup produced by maple trees, the migration of the trees and the results of this on the industry.

3) Many people are involved in the production of maple syrup on a local and a commercial basis. Their careers may be seriously affected by any changes the climatologists predict for the future. Note all the possible careers that exist in this industry and careers that will influence the industry, i.e. syrup farmers, laborers, climatologists, food scientists, etc.. Each student should select one career and research it, as fully as possible, describing the present status of it and how the future predictions of climate change might influence this.

4) Autumn colors, the alteration of deciduous trees from different shades of greens to an array of reds, oranges, golds and yellows is a spectacular and incredibly beautiful natural event. Can you select another event similar to this, that occurs on a regular basis? Or perhaps an event that may happen in a five, ten or twenty year cycle? Describe your feelings towards such events.

5) Are there areas in your state, or a nearby state that have "relic ecosystems" left over from the last glacial cycle? If so, why have they remained? How are they different from the present flora/fauna?

Teacher Background Information:

Ohio Sea Grant Education Program. 1992. "GLOBAL CLIMATE CHANGE IN THE GREAT LAKES: Understanding Climate Models." *Global Change in the Great Lakes Scenarios.* Columbus, Ohio: Ohio Sea Grant Publications (Ohio State University, 1314 Kinnear Rd., Columbus, OH 43212-1194)
This is essential reading for teachers and students using this activity. A very readable account of the use and significance of models in scientific predictions concerning the climate. It also examines policy decisions in the face of global warming.

Ohio Sea Grant Education Program. 1992. "GLOBAL CLIMATE CHANGE IN THE GREAT LAKES: How will Forests in the Great Lakes Region be Affected?" *Global Change in the Great Lakes Scenarios.* Columbus, Ohio: Ohio Sea Grant Publications, Ohio State University, 1314 Kinnear Rd.
This scenario examines sugar maple and other tree species' migration. It represents a contemporary collection of research in this area, but in an understandable form. It projects the types of forests that may exist in northern Minnesota in less than 100 years. This scenario also examines other reasons for forest decline, such as acid precipitation, heavy metals, and the economic

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implications of this alteration to the forest community.

Pastor, J. and Post W. M. 1988. Response of northern forests to CO_2-induced climate change. *Nature* 334 (7) : 55 - 58.
A more scientific account of tree migration as a result of climate change but nonetheless, worth reading and selecting specific points for this activity. It examines numerous tree species and different areas of the Great Lakes Region, including parts of Canada.

References:

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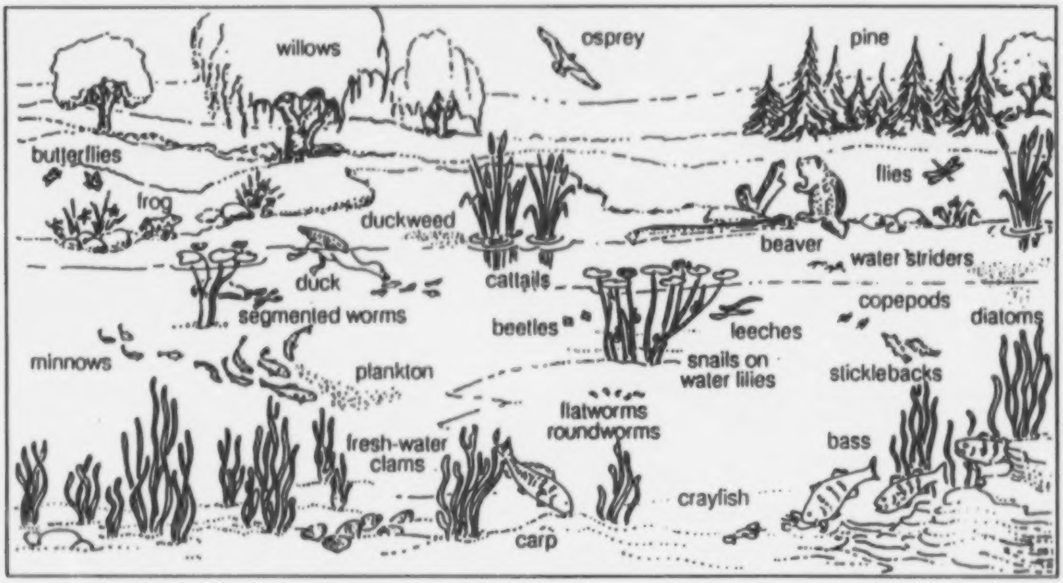
Drawings courtesy of the Great Smoky Mountains National Park Archives.
Original activities contributed by teachers Christina Pryor and Linda Floehr.

Have To Have A Habitat


willows
osprey
pine
butterflies
frog
duckweed
flies
beaver
water striders
duck
cattails
copepods
diatoms
segmented worms
beetles
leeches
minnows
plankton
snails on water lilies
sticklebacks
flatworms roundworms
fresh-water clams
bass
crayfish
carp

(Illustration by L. Farr, The Ohio State University, 1992.)

An ecology song entitled "Habitat, habitat," claims that "you have to have a habitat to carry on." Scientists know that the single factor responsible for most extinctions is loss of suitable habitat. The game in this activity can help students realize the types of factors that threaten biological diversity by affecting habitats.

Many of the activities in the Biodiversity set introduce data demonstrating that populations of plants and animals are under stress. What are the sources of the stress? How do they affect populations directly and indirectly? Are there other factors that threaten species besides those related to habitat?

Scientists define ***habitat*** as the place where an organism lives and carries on its life processes. Specifically, the habitat may be a cave, tree, sand hill, rotten log, air, deep ocean, river bed, etc. For purposes of this activity, habitats will be classified as land, air and water. Most organisms occupy only one of these habitats but use the other two. Some organisms, like mosquitoes and river otters, occupy different habitats at different times.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

Objectives: When you have completed this activity you will be able to:

1) describe things that can happen to air, land and water, damaging these habitats for living things.
2) identify stresses on plants and animals that are not specifically related to the physical environment.
3) analyze the impact of habitat stress on certain organisms.

Earth Systems Understandings (ESU): This activity focuses on ESUs 2, 3 and 4, however the following ESUs are covered in the Extensions — 1, 5 and 7. Refer to the Framework for ESE for a full explanation of each ESU.

Materials: overhead projector; Transparency Master #1; washable marking pens; chalk and chalkboard; set of *CHANGE* cards; and set of *SPECIES* cards.

> [Advance Preparations. If the entire class is to work together on the game, make a transparency of Master #1. Copy the *CHANGE* cards onto card stock or glue onto a manila folder, cut apart on dashed lines, put into a deep bowl or hat, and mix. Do the same with the *SPECIES* cards. If small groups will work on the game instead of the entire class, each group will need a laminated paper copy of the Master, a washable marker, a set of shuffled *CHANGE* cards in an envelope, and a set of *SPECIES* cards to divide among themselves. Instructions given are for playing the game as a class.]

Procedure:

1) When the game begins you will receive a *SPECIES* card. Be alert during the game to the dangers of habitat destruction for your species.

> [You may want students to do advance research, draw a picture of their species, and write a paragraph about its habitat and ecology.]

2) The Master serves as the game board. The teacher draws the first *CHANGE* card and reads its contents. Together the class decides whether the change described on the card will most impact living things by changing the habitat or the ecology (relationships within the environment).

3) If the *CHANGE* affects habitat, decide if Air, Water, or Land is most affected. Put an X through one of the game board squares for that habitat if it is threatened or destroyed. Erase an X if the change is a helpful one for preservation of habitat. For each instance of habitat destruction, one organism from that habitat is lost. The student who "becomes extinct" should read the species card aloud and then draw the next *CHANGE* card. Organisms may be added by positive habitat changes. (A student without species cards may receive a card.)

4) If habitat is not threatened by the *CHANGE* card drawn, list the factor on the board under the heading OTHER IMPACTS. Tell what species is affected and if the

factor increases or decreases population. Eliminate or add a species depending on the impact of the card.

5) When one habitat is completely full of Xs, the environment has been destroyed. The game is over, even if some organisms from that habitat have temporarily survived. They will not last long. All living things need a complete ecosystem to survive.

> [Enough *CHANGE* cards are included for the game to be played twice. The environment is not lacking for changes! When you have finished playing the game twice, perhaps once with the whole class and once with your team, sort the *CHANGE* cards into Air, Water, Land and Other Impacts.]

6) Write a paragraph in which you discuss how habitats are destroyed, and how those factors can make living things become endangered or extinct.

7) Analyze whether the *CHANGES* you discovered were mostly natural or caused by humans. Which *CHANGES* could be prevented?

8) List the species that were threatened by environmental changes in this game. For each species, identify whether its value is symbolic (like the bald eagle symbolizes the USA), charismatic (lovable or fascinating like pandas), economic (like food crops or animal hides), or ecological ("keystone" species that establish or maintain the ecological conditions of an area, like prairie dogs).

> [For more information on these types of species, refer to Mullins, et al., 1989. *Interpreting Biological Diversity*.]

9) Do you want to save all the species in the habitat game? Why or why not? What would be lost if we allowed (or caused) these species to become extinct?

10) How can habitats be restored? For each way the class can think of, erase one X. Determine if a healthy ecosystem can be reconstructed before the remaining organisms become endangered as well. Do you know of any areas where this restoration could be practiced.

> [**Alternative "Bingo" method of play:** Have students draw their own Bingo board with 5 squares across and 5 squares down. In each square, they write an A, W, or L in approximately equal proportions for Air, Water, and Land Habitats. As *CHANGE* cards are drawn in their groups, they decide individually which habitats are affected, and they cross out those squares. When all the squares of one habitat are gone, the student "dies." Most members of the group will die simultaneously. The advantages of this alternative method of play are that it moves faster and individuals are more involved. The disadvantage is that *SPECIES* cards are not used.]

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Note: Listed below are suggestions teachers have made to speed up play and to localize the activity. Try any or all as needed in your class.

1) Use local organisms (not necessarily endangered), as the species.
2) When one species becomes extinct, others that depend on it die too.
3) Let each *CHANGE* card have as wide as impact as possible, affecting all habitats and many species.
4) Instead of drawing *CHANGE* cards, show slides of change and have appropriate species identify the impact on them.
5) Give many students the same species, so a single *CHANGE* can impact more individuals.
6) For full class play, let groups represent different biomes: tundra, desert, deciduous forests, etc. *CHANGE* cards are then capable of impacting a whole ecosystem.
7) Play the game outside. Mark out a section of the school yard as the game board. The students could have prepared a name tag, or a graphic of the species they will represent. The students then stand in the habitat square that the organism inhabits. The game begins. As each species is eliminated, the student representing it leaves the board. Once all the species are gone, discuss the situation with the students. When the game is finished, explain to the students that the game board could represent their local area, state, region, nation, continent or world. Once inside, the discussion may continue.

Extensions:

1) One of the contemporary methods of expressing views concerning issues and problems that face the planet is through music. Listen to some of the music of John Denver, Dan Fogelberg, Bruce Hornsby and the Range, and other artists. Their songs have very clear messages concerning the loss of habitat, our impact on habitats and the need for a clearer understanding of our relationship with our environment.

Answer some or all of the following questions about the music you have listened to:

- a) what event(s) is (are) the artist singing about?
- b) what type of mood is implied by the music, by the artist's voice?
- c) examine the lyrics of the song. How factual are they?

Select one of the events mentioned by the singer and investigate this issue/problem. Examine the information detailed in the song and compare it with some other type of media — newspaper clippings, radio or TV presentations, etc.

2) The various habitats and biomes around the world have taken millions of years to evolve and develop the intricate mechanism called the web of life. Describe how humans have influenced this web of life. Once a habitat has been altered, is it possible to restore it? Explore the possibilities using the MAXIS software *SimEarth* available in IBM and Macintosh versions.

3) A new problem in relation to habitat loss has appeared over recent years — fragmentation. Clear-cutting of forests, urban development (highway and home

construction), etc. fragment habitats. What is the result of this process on the biodiversity of life present in the original habitat? Animals have used the same migration routes for thousands of years. Examine the influence of fragmentation of habitats in relation to migration patterns and animal population.

4) Habitat preservation is one of the important factors in preserving biodiversity. While the developed countries are attempting to conserve habitat, much is destroyed in the poorer nations because of economic demands. What impact does this have on migrating song birds?

5) Ecologists study ecosystems and the dynamics involved in animal and plant population growth. However, the methods of study that ecologists use have changed dramatically over the years. Examine the career of one ecologist — such as Diane Fossey (Gorillas in the Mist) or Jacques Cousteau — and how her/his work has contributed to our knowledge of the natural world.

Teacher Background Information:

Halle, F. 1990. "A Raft Atop the Rain Forest." *National Geographic.* 178 (4) : 129 - 138.
This is an excellent article detailing the heights that some scientists reach to examine the biodiversity that exists in the rain forest. Halle documents the different approaches scientists use to explore the canopy of this community. It also helps to dispel the traditional stereotype of the research scientist and may be useful to share with your students.

Silver, C. S. and DeFries, R. U. 1990. *One Earth One Future, Our Changing Global Environment.* Washington D.C.: National Academy Press.
This book examines the various aspects of global change occurring to the natural environment. It investigates specific topics such as global warming, coastlines and rising seas, vanishing forests and vanishing species, etc. It also analyzes the influences of various changes on habitats and ends with a global perspective.

Trust, J. 1991. "A Habitat-Forming Experience: Cultivating a native plant ecosystem." *The Science Teacher.* Dec. 22 - 27.
This article documents the process of habitat construction on a school site. Scientists and society are depending on this action as a means of protecting certain plant and animal species. Transplantation of such species to these new sites is a major concern for scientists and environmentalists. This article raises the question: is it really possible to artificially produce a habitat, a replica of a living system?

Air	**Land**	**Water**	**Land**	**Air**
Air	**Water**	**Air**	**Water**	**Land**
Land	**Air**	**Land**	**Land**	**Water**
Water	**Land**	**Water**	**Air**	**Land**
Air	**Air**	**Land**	**Water**	**Air**
Water	**Water**	**Air**	**Land**	**Water**

Habitat Game Board

Transparency Master #1

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CHANGE CARDS (print on card stock, laminate and cut apart)

Cars are the greatest single source of greenhouse gases and the largest single cause of ozone smog.

Because of auto emissions in Mexico City, 7 out of 10 infants there have blood lead levels in excess of World Health Organization standards

Every day the US produces enough toxic waste to fill the New Orleans Superdome four times.

Disease infecting a monoculture of food plants or animals can wipe out the entire species because it lacks genetic diversity. (Diversity is safe; monoculture is risky!)

Early in the Persian Gulf War in 1991, the ruler of Iraq dumped over 1.1 billion liters of oil into the Gulf. This resulted in a spill 27 times larger than that from the Exxon Valdez in 1989.

Over 50% of the US population lives within 50 miles of the coastline. This results in tremendous development pressures: hotels, pedestrians, lights, and curious beachcombers disrupt the natural life along the beach.

Toxic chemicals and heavy metals can leach out of sanitary landfills, poisoning nearby land and water.

Do-it-yourself mechanics dump an Exxon Valdez worth of used motor oil on the land every 2.5 weeks.

DDT, a dangerous pesticide banned in the US in 1972, is still used by other countries. Air currents carry it into this country.

About 90% of the PCBs and all the toxaphene pesticide in Lake Superior got there by way of air currents from other parts of the continent.

Commercial fishing sometimes kills other species than those it can sell, either because catching them accidentally is common, or because the other species is a nuisance.

Scientists predict that global warming will alter crop patterns and change the types of pests common in different areas of the world.

Half the land in an average American city and 2/3 of the land in Los Angeles is used for cars (parking, driving, etc.)

According to the World Resources Institute, about 8 million hectares of forest are cleared in Brazil every year, compared to about 1.5 million in 1985.

The Food and Agriculture Organization (FAO) of the United Nations estimates that the world is losing forests at the rate of up to 20.4 million hectares per year, an area the size of Panama every 12 months.

Under conditions of global warming, there would eventually be no tundra.

Grasslands and deserts will increase their global extent with greenhouse warming, and droughts and windstorms will be more frequent and severe.

The frequent burning of savannas by farmers and herdsmen of Africa appears to contribute to unusually high levels of ozone and acid rain over the forests of central Africa.

Spring snowmelt in the Northeast US delivers an "acid shock" to streams and ponds just at a time when fish and amphibians are depositing eggs.

Untreated sewage contains pathogens that can affect human health and nutrients that encourage algal growth in water.

Surface mining disrupts natural vegetation and contributes to water pollution.

An increase of global atmospheric temperature by 1/2°C could increase annual precipitation by 10 percent, mainly at high and low latitudes. Most agricultural production today occurs in the middle latitudes.

Ozone depletion increases the amount of biologically harmful ultraviolet rays that reach the surface of the earth and water.

By 2025, it is estimated that the world population will be 8.5 billion, and 60% of that will be urban.

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US farmers used 475,000,000 lb. of pesticides in 1986, down from 650 million in 1976.

Captive breeding programs for some birds are largely unsuccessful.

The Indian Ocean Sanctuary provides a refuge for all whales, and the United States does not allow whaling within 200 miles of its own coasts.

The U.S. Endangered Species Act and the CITES treaty have stopped nearly all imports of endangered cats into the Unites States.

The Oil Pollution Act of 1990 establishes new standards for the oil industry that should lower the risk of oil spills.

Organizations such as the World Wildlife Fund sponsor research on many Asian and African endangered species in order to facilitate their preservation.

When Japan signed the CITES Treaty, there were 9 species that it reserved (stated that it will not comply with restrictions on those species.) Among the nine were several kinds of endangered turtles.

With the discovery that old growth forests are more productive than once thought, there is increased pressure to preserve these forests.

The U.S. Fish and Wildlife Service and the Wyoming Fish and Game Department have started an intensive management program to study black footed ferrets and provide suitable habitat for them.

While captive breeding programs to help the Nene have been fairly successful, when the birds are released into the wild their numbers are reduced by habitat loss and exotic predators.

Although Eskimo Curlews were thought extinct for many years, biologists have seen increasing numbers of them for the last decade, giving some hope that the species is recovering.

Many species of flightless birds evolved in New Zealand because few ground predators were present. However, since people arrived they have introduced many new ground species of animals which are seriously threatening the flightless bird populations.

SPECIES CARDS

(Print on card stock, laminate, cut apart, and divide among students.)

INFANTS in developing countries have a higher death rate from air pollution than those in developed countries.

ROSY PERIWINKLES are a tropical rainforest plant whose extracts are being used to treat leukemia.

About 95% of all white eggs in the US come from WHITE LEGHORN CHICKENS. This makes egg consumers needlessly dependent on one species. Disease could seriously impact this agriculture commodity because it is a monoculture.

When an oil spill occurs, the heavier fractions of petroleum sink and destroy SHELLFISH beds under the water.

The gentle DUGONG, cousin of the manatee, is supposedly the origin of the mermaid myths. One of the largest remaining populations in is the Persian Gulf, where it is threatened by oil as it surfaces to breathe.

SEA TURTLES come ashore to lay their eggs. Their nesting grounds are also among the favorite beaches of the world.

The last remaining CALIFORNIA CONDORS have been captured for captive breeding to save the species, whose natural habitat has all but disappeared.

BLUE WHALES grow to be longer than a schoolbus. It is estimated that whalers have taken all but 5% of the original blue whale population.

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STURGEONS were nearly extirpated from the Great Lakes in the late 1800s because these huge fish would swim through fishing nets and destroy them. Commercial fishers hauled the sturgeons out and burned stacks of them on the shore like logs.

TSETSE FLIES, which carry the pathogen for sleeping sickness, will probably not survive the changes associated with global warming.

While most animals can migrate to higher elevations or latitudes as their local climate changes, TREES can't "get up and go." Plant migration is unlikely to keep pace with changing climate; some tree species will die.

UV-B radiation damages FISH LARVAE and juveniles, as well as PHYTOPLANKTON, the base of the aquatic food chain.

BALD EAGLES develop reproductive difficulties when they eat fish contaminated with PCBs through the food chain.

The forest home and food supply of PANDAS is rapidly disappearing.

Almost all of the SPOTTED and STRIPED CATS are rare or endangered because their skins make fashionable coats.

The HAWKSBILL TURTLE is prized for its fine tortoise shell that is used for jewelry and artwork. Imitations were found in the 1930s, but they were not as beautiful. The hawksbill is an endangered species.

The future of WHEAT, one of our staple grains, is now threatened because its wild and weedy relatives have been eliminated. We have seriously limited our ability to improve varieties and extend the range of the crop.

The old growth forest of the Pacific Northwest is critical habitat for the NORTHERN SPOTTED OWL. When the size of the timber stand is reduced below a certain area, the owl will not have sufficient range to survive.

The ESKIMO CURLEW, a small northern shorebird from Alaska and northern Canada, is endangered because of over-harvesting.

KIRTLAND'S WARBLER lives only in forests of young Jack Pine in Michigan. If climate change disrupts the tree habitat, the birds will not have a home.

The RED WOLF was declared endangered in 1967 because of habitat loss and bounty hunting. The red wolf was declare extinct in the wild in 1979. Reintroduction of captive red wolves is underway.

Black-footed FERRETS were almost destroyed by eating poisoned prairie dogs. There are now over 20 animals. Preservation is possible!

The NENE, state bird of Hawaii, has been threatened by alien species that prey upon it and also compete with it for food. By 1950 there were only 50 birds left on the Big Island of Hawaii. The NENE is now protected by fencing out the alien species and predators.

RIVER OTTERS, once nearly hunted to extinction, are being reintroduced to the wild in many parts of the country. Oil and other water pollutants pose a threat to the reintroduction of this species.

PEREGRINE FALCONS have suffered declines in population because the pesticide DDT causes reproductive problems for them.

The BROWN PELICAN, Louisiana's state bird, is highly sensitive to pesticides. Even low concentrations of pesticides can kill their embryos.

HUMANS breathing smog-filled air have increased amounts of respiratory problems. Toxic chemicals buried in the Love Canal in Niagara Falls forced HUMANS to move away.

FISH exposed to toxic chemicals and heavy metals can grow tumors on their skin.

Acid rain can destroy the cells that contain chlorophyll in the leaves of TREES.

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FISH will die when their water becomes choked with algae and there is very little oxygen.

INSECT LARVAE will not survive being buried by sediment eroded from mines.

TROUT EGGS will not hatch when the acidity of the lake water is too high.

Species such as the ARCTIC FOX require the tundra habitat to survive.

The WOOLLY SPIDER MONKEY, which is the most endangered South American primate, is dependent on forest habitat.

The SMALL WHORLED POGONIA, an orchid, inhabits open areas of hardwood forests from Ontario to Georgia. Habitat destruction is reducing its' population.

BRADY'S PINCUSHION CACTUS lives in the deserts of northern Arizona. Population is declining due to habitat loss and overcollection.

The largest butterfly in the world, the QUEEN ALEXANDRA BIRDWING BUTTERFLY, is declining in number due to loss of its' habitat - the tropical rain forests of Papua New Guinea.

The KAKAPO, a parrot of New Zealand, that is unable to fly but glides. Introduced species are preying on and endangering this bird.

The GREEN PITCHER PLANT inhabits the wetlands of Alabama, Georgia and Tennessee. Habitat loss and overcollecting are causing a decline in population.

A North Carolina Snail, the NOONDAY SNAIL, lives in the states forests. Is endangered due to habitat loss.

The disease, MALARIA, is on the increase since 1985. 800,000 children died in 1990. This increase is due to the increased resistance of malaria-carrying MOSQUITOES to insecticides and the reduced use of DDT spray.

The LEATHERY PERIWINKLE of Madagascar can be used as an effective treatment of blood cancers, primarily childhood leukemia. It is endangered due to loss of habitat and pollinators.

The only habitat of the rare plant, the PONDBERRY SHRUB, was purchased in Missouri to protect this species. The plant requires sandy soil, swale and ravine to grow.

The LANGE'S METALMARK BUTTERFLY inhabits a few acres of the Antioch dunes in California. If not for the U.S. Endangered Species Act, it would probably be extinct.

The three-inch SNAIL DARTER FISH was discovered on the Little Tennessee River in 1973, while a dam was being constructed. Despite several protests from environmental groups and a Supreme Court decision to halt construction of the dam, construction continued. This virtually wiped out the population of this species in this area. However, since then this fish species has been discovered in other rivers in the area.

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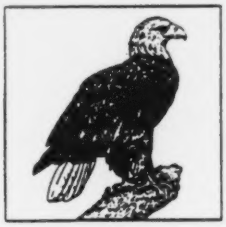
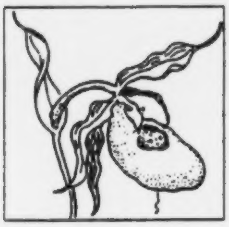
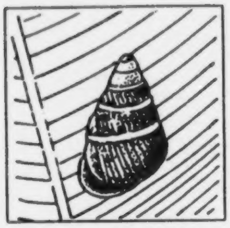
IN FOCUS:
Endangered and Threatened Species



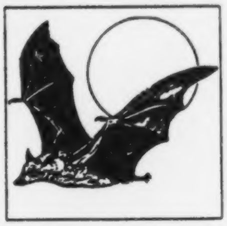
BALD EAGLE



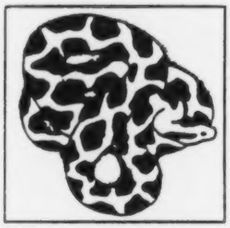
ORCHIDS



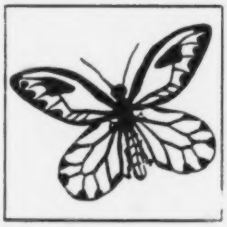
LITTLE AGATE SNAILS



FLYING FOXES



INDIAN PYTHON



BIRDWING BUTTERFLIES

There is a magnificent variety of life that inhabits the Earth. Unfortunately, humans are the species responsible for the unprecedented speed with which other species are becoming extinct. At the same time, humans can also protect these endangered species. Humans are immensely fortunate to be alive now and have a chance to save the diversity of animal and plant species which still exist.

As you study endangered species, you will encounter information on some new species and on some you have heard about often in the news. This activity provides an opportunity for you to learn more about a species that interests you, and to help others learn about it as well. Your class will produce a booklet of fact sheets about threatened and endangered species and distribute it to other school classes.

Objectives: When you have completed this activity you will be able to:

1) identify three sources of current information on endangered and threatened species.
2) analyze and compare the issues surrounding several species whose populations are endangered or threatened by human activity.
3) demonstrate how desktop publishing can be used to produce communications on environmental issues.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

53

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Earth Systems Understandings (ESU): This activity focuses in ESUs 2 and 3, however, the following *ESU*'s are covered in the Extensions — 1, 4 and 7. Refer to the Framework for ESE for a full explanation of each ESU.

Materials: microcomputer with desktop publishing program; access to references with current science content (e.g. World Book *Science Year,* Dialog databases, EcoNet conferences); *Reader's Guide to Periodical Literature;* cooperation of local scientist(s) to review information before distribution; Appleworks database fact sheet.

Procedure:

1) With your team of one or two other students, select an endangered or threatened species that interests you. Lists are available in other activities in this unit and from your state's department of natural resources. Make a class list on the board so that duplication is avoided.

2) Search the available information and locate at least three references that tell you different things about the species you selected. Be sure you identify why the species is in trouble, where it lives, how many are estimated to be alive now, and why people think it should or should not be protected. The people who read your fact sheet will also want to see a picture of the organism and learn about its characteristics and general life style.

3) Write a draft of a fact sheet by hand so you will be ready when your team gets access to a computer. Since you do not have much space to write (two sides of one page at the most, please), you will have to choose your information wisely. A sample of a student fact sheet is attached, not as the BEST example, but to help you generate ideas.

4) Sketch how you will design a page so that it is attractive to readers. It needs a headline, at least one picture (xeroxed is fine), and some subheadings that help to organize the information for the reader. (See Northern Spotted Owl, as an example.) Most editors agree that two or three columns on a page make the reading less tiring than if words are typed all the way across the page without columns. Try various formats until you decide which is best for you.

5) Use your desktop publishing program to produce the fact sheet. If your school has a scanner, perhaps you can have your illustration scanned in for easier fitting into the text. If not, size the picture on a copy machine and paste it onto the printed sheet with a glue stick or "peelable" tape.

6) When all the fact sheets are completed, develop a computer database of the species studied by all teams in all classes. (Instructions for an AppleWorks database are given in the fact sheet at the back of this book.) Include categories that will allow you to sort the organisms by taxonomic group, geography, threatened *vs.* endangered, natural *vs.* human cause of threat, or other properties/characteristics.

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7) Prepare a summary sheet using comparisons from the database and answering the following questions:

   a) were more plants chosen for the activity or more animals? Why do you suppose this happened?
   b) which continent had the largest numbers of endangered species? the most threatened species?
   c) describe the factors that endanger plants and animals. Which seem to be the most destructive factors?
   d) what does it appear would have to be done to save the species you studied? Is saving all the species desirable? Discuss this with your classmates, then read E. O. Wilson's "The Current State of Biologcial Diversity."

8) Ask some scientists at a nearby college or industry to read the class' fact sheets and make suggestions before a booklet is printed. Perhaps a scientist would write an overview of the project to include in the booklet.

9) Copy, bind and distribute your booklet of Biodiversity Threatened to others in your school and at home. Use your information to try and save at least one species in the activity.

Extensions:

1) Although people tend to focus on animals when the words endangered or threatened are mentioned, plants also face these problems. At present whole habitats may become endangered or threatened. How valuable are the plants and animals to the habitat and vice versa? Is the planet itself threatened? Express your feelings on this topic — create a poster which expresses these sentiments on this situation.

2) The Earth has evolved a mechanism for sustaining life on this planet. Humans have disrupted this balance. Have previous upsets in this balance occurred and threatened plant and animal species? What were these and when did they occur? Should humans be worried about the present impact on plant and animal populations?

3) Is it necessary to maintain Biodiversity? Why? What use is it to humans? Should a plant or animal's survival depend on whether or not it is of use to humans? Does an organism possess an intrinsic value?

4) If you wanted to study biodiversity, what type of career would you choose? What type of training and background would you require? Do you know anyone who studies biodiversity? Interview some of the scientists who have read your information sheet. Ask them questions concerning biodiversity and if they study it, how they became involved in this career.

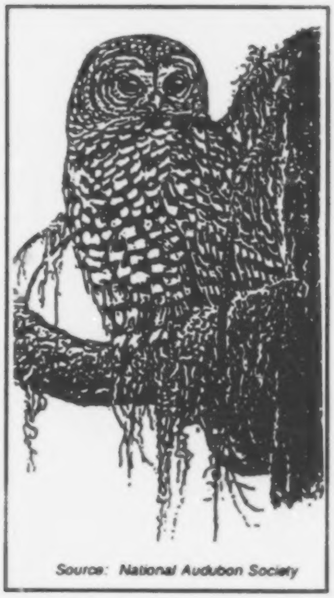
the
Northern Spotted Owl
a threatened species

On June 26, 1990, the U.S. Fish and Wildlife Service officially declared the northern spotted owl, Strix occidentalis caurina, a threatened species and placed it on the Threatened and Endangered Species List.

Threatened species are those whose numbers are declining, but which are not in immediate danger of becoming extinct.

Description

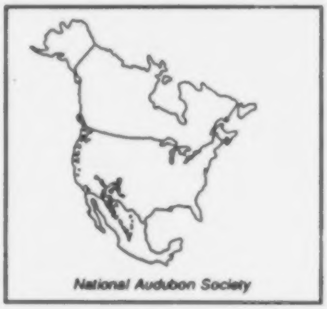
The northern spotted owl is about the same size as the common crow. The female is larger than the male. It is dark brown with white spots and dark eyes. They are round, fluffy birds with a round head and no ear tufts. They have been known to allow humans to come as close as 6 to 9 feet before flying away.



Source: National Audubon Society

Habitat

Evergreen forests that contain very old trees, usually 200 years old or older, are the favorite habitat of the northern spotted owl. It has also been found in forests of younger trees (100-200 years old), however. In general, a forest with a thick canopy and a dense underbrush are preferred.



National Audubon Society

Range

The northern spotted owl can be found in the rain forests of the Cascade Mountains in the Pacific Northwest. The range extends from southern British Columbia to San Francisco Bay.

Voice

The northern spotted owl's call consists of 2 or 3 *hoots*, followed by a louder and longer *hooo-ah*. The calls of the female are higher pitched than those of males.

Breeding Pairs

It is estimated that there are 3,000 breeding pairs of northern spotted owls in the Pacific Northwest. They usually pair for life, but occasionally mates do change.

Nesting

Northern spotted owls prefer to nest in old-growth Douglas-fir trees. The average nest is 90 feet off the ground. They rarely build their own nest, preferring to use abandoned hawk nests. They have been known to use the same nest year after year.

Eggs are laid in April or May. Incubation is about 30 days. The clutch (number of eggs laid) size is usually 2. However, sometimes 3 or 4 eggs can be found in a nest. The young owls are usually ready to leave the nest when they are 35 days old.

Diet

Because it hunts at night the northern spotted owl is classified as a nocturnal raptor. Its diet varies depending on the area in which it lives. In general, flying squirrels and red tree voles are its favorite foods. In mixed conifer stands (mature and old-growth) their diet consists mainly of woodrats. They are known to store excess food for future meals.

At Issue

The habitat of this owl, the Pacific old-growth forest, is rapidly being logged. While the lumber industry makes a case for jobs versus owls, scientists fear that habitat loss will spell extinction for the species. The extent of old-growth forest in the northwest U.S. has declined by 86% since 1940 in Olympic National Forest alone. With only 14% of its owl habitat remaining, this forest is a prime example, but unfortunately not an isolated one.

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Teacher Background Information:

Bergman, C. 1990. *Wild Echoes. Encounters with the Most Endangered Animals in North America.* Seattle: Alaska Northwest Books.
A book that deals with some of the animals that face extinction on this continent. Examining the current status of the wolf and California condor to the extinction of the dusky seaside sparrow, the author also investigates the black-footed ferret, once thought to be extinct. Bergrnan makes some comments on what needs to be done to save these animals.

Dunbar, R. 1985. *World of Nature.* New York: Gallery Books.
A wonderfully photographic book showing many of the animals and plants associated with different regions around the world. Since this book was published many of these animals have declined in number. This would be a good example of the rate at which species are declining.

Wilson, E. O. 1992. "The Diversity of Life." *Discover.* September. p. 45 - 68.
An excellent article documenting the current status of the natural environment, the loss of biodiversity and the problems that humans face. Wilson traces the development of the planet and that wonderful, intricate mechanism called life. He cites many past examples of extinctions and closely examines the current rate of extinction and its implications.

References:

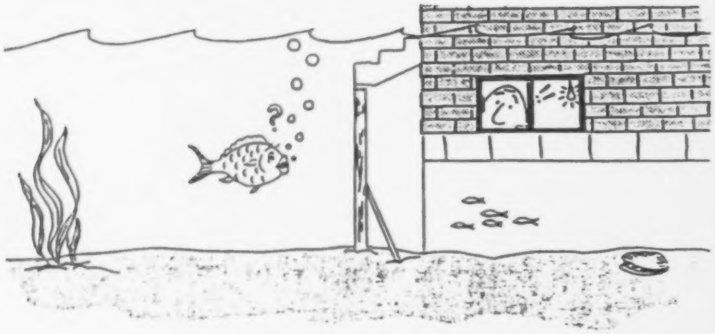
Collins, N. M., Sayer, J. A. and Whitmore, T. C. 1991. *The Conservation Atlas of Tropical Forests — Asia and the Pacific.* New York: Simon and Schuster.

Nilsson, G. 1986. *The Endangered Species Handbook.* Washington D.C.: The Animal Welfare Institute.

Wilson, E. O. 1988. "The Current State of Biological Diversity." In *Biodiversity.* Washington D.C.: National Academy Press.

EcoNet, an electronic network of current environmental information, is a subscription service available using a modem and local telephone number. Refer to the EcoNet fact sheet at the back of this book.

How High's the Water?



© Ohio Sea Grant Publications (1990).

Two of the predicted changes to accompany global warming are a sea level rise of up to 1.2 meters (Figure 1) and a drop in the water level of the Great Lakes by 2.5 meters, both caused by a doubling of CO_2 in the atmosphere.

Such changes will have serious impacts not only on cities, harbors and homes, but also on the recreation and tourism now taking place on the shores of those bodies of water.

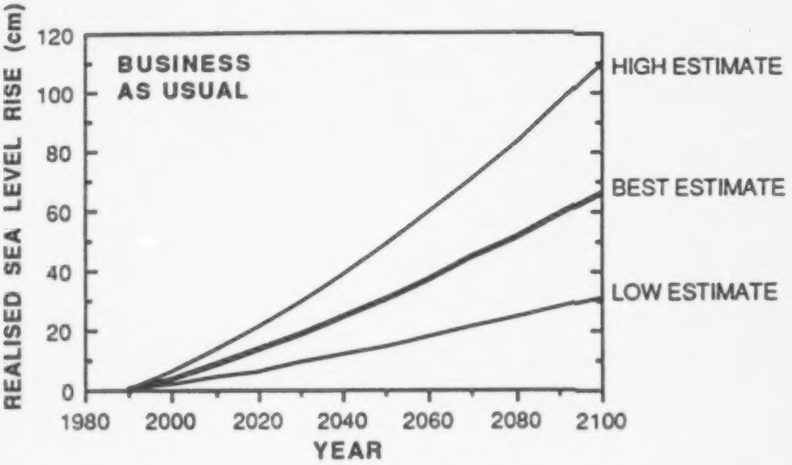


Figure 1. - Sea level rise as a result of global warming. (If we don't do anything different.) (Source: Houghton, et al., *Climate Change: The IPCC Scientific Assessment*, 1990.)

Sea level is expected to rise because of four major climate related factors that will result from global warming:

1) melting of mountain glaciers,
2) melting of the Greenland ice sheet,
3) melting of the Antarctic ice sheet, and
4) thermal expansion of the oceans.

An increase in the global temperature will cause mountain glaciers, and the Greenland and Antarctic ice sheets to melt. However, as liquids expand when heated, an increase in global temperatures would cause thermal expansion of the oceans, thus increasing the space that they now occupy. The consequence of these events would lead to an increase in sea level.

The amount of sea level rise possible by each of these climatic factors is listed below in Table 1.

	Thermal Expansion	Mountain Glaciers	Greenland	Antarctica	TOTAL
HIGH	14.9	10.3	3.7	0.0	28.9
BEST ESTIMATE	10.1	7.0	1.8	-0.6	18.3
LOW	6.8	2.3	0.5	-0.8	8.7

Table 1. - Factors contributing to sea level rise (cm), 1985 - 2030. (Source: Houghton, et al., *Climate Change: The IPCC Scientific Assessment*. 1990.).

Many coastal and wetland areas are artificially maintained for the purposes of human development. Wetlands are drained for home construction; long stretches of beaches are created for sunbathing; land is reclaimed for farming and cities. It is likely that the maintenance of these areas will be unable to keep pace with rising sea levels. The concepts that are studied in this activity include: *changes in coastal water levels, global climate change and the impact of these factors on people.*

Objectives: When the activity has been completed, you will be able to:

1) visualize the impact of climate change on your favorite coastal recreation areas.
2) anticipate lifestyle and recreational changes that would accompany the change in water levels.
3) state the reasons for the differences in sea and lake levels expected.

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3 and 4, however, the following ESUs are covered in the Extensions — 1, 5, 6 and 7. Refer to the Framework for ESE for a full description of each understanding.

Materials: photographs or travel brochures of structures and natural features on shores of the ocean and Great Lakes (provided by students if possible); blue transparent sheets to represent water; wall map of North America; push pins; string; drawing paper; writing paper; pencil or pen.

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Procedure:

1) Bring to class a photograph or other picture of a place you have visited along the shore of North America. You may substitute a magazine picture if you can identify its location. Find the location of the site on a wall map and put a pin in that location.

2) Within the class try to get pictures from a wide variety of coastal areas -- cities, beaches, wetlands, condos, campsites, waterfowl nesting areas, marinas, etc. Glue each picture on cardboard cut just a bit larger than the picture.

3) In the seashore pictures assume that every story of a multi-story building is 3 meters high (4 meters for office buildings). Estimate the height of beaches, trees, and other natural areas using something you know in the picture.

4) Find the level of the sea's predicted rise and cover the picture with blue transparent film to that level to show what will be underwater! Cut the blue film larger than the picture and glue it onto the edges of the cardboard around the print. Mount the new picture on the bulletin board and connect it with string to the pin noting its location on the map.

In the Great Lakes area, global climate change is predicted to bring an interesting set of climate circumstances: slightly more rainfall, but such an increase in temperature and demand for water for human uses that evaporation and lack of snowpack will cause a net loss of water. Thus while sea levels rise, the lake levels will drop. In recorded history the lowest lake levels have not been below 1 meter less than the present, yet a drop of up to 2.5 meters is forecast for a doubling of CO_2. Most of the Great Lakes shoreline is residential, but there are areas of heavy industry and shipping, agriculture, forests, and some wetlands that attract millions of migratory waterfowl.

5) If your coastal recreation picture is on the Great Lakes shore, imagine what is underwater to a depth of 2.5 meters. Instead of losing some real estate, your area will gain some! With your drawing paper cover the existing water line and add a new lower one. Draw in what you expect to see when this new territory is exposed. (Think about what will happen to the boat dock, launch ramp, water intake pipes, zebra mussel colonies, and such.) Post your new picture on the bulletin board and connect it with string to its map pin.

6) Look at the array of coastal recreation impacts depicted by your class. Imagine the total impact brought about by changes in coastal water levels. Write a creative essay about your nostalgic trip in 2030 to the shore of your childhood, and your discovery of these changes.

7) Answer the following questions based on what you observed from this activity.

a) Identify a U.S. coastal area and describe the impact of rising coastal water levels on the following situation:

   i) damage from a hurricane or tsunami hitting the area.
   ii) animal habitat and plant growth in wetlands.
   iii) beach front resort hotels and condos.
   iv) urban water front renewal projects.

b) List the costs that would be associated with rising sea levels in the selected areas. Include the financial costs of the situation. Also list environmental or social costs that may not be paid for in dollars.

c) Some people say we cannot afford to make the changes in lifestyle that will prevent global climate change and sea level rise. On the basis of your answer to #2 above, how would you respond to such people?

> [The coastlines of the U.S. are sometimes shifting up or down because of local Earth processes, so changes in coastal water levels will affect different coasts in different ways. You may wish to follow this activity with one entitled, "Sea Level Change? Well, It Depends."]

Extensions:

1) Describe how the rising or falling of coastal water levels will impact other systems of the planet, i.e. atmosphere, biosphere, cryosphere and lithosphere.

2) If, as a species, we continually alter the planet's climate, is there another planet in this solar system that the Earth may resemble in the future? Discuss and give reasons for your answer.

3) Historically, the oceans have been viewed in very different ways, from areas to be conquered to places teeming with life (including sea monsters!), from places of great rugged and violent beauty to vast dumping grounds. Many present ideas concerning the oceans are still founded in these past perceptions. Select one of the above views (or cite your own), research it and write a short story or poem or compose a rap about it.

> [At least one student should select the ocean as an area of great beauty and trace how it has been represented in art, literature, song, etc. from the past to present times. If not, the teacher should create a presentation on this topic.]

4) How quickly can the plants and animals on the planet evolve or change to meet this new challenge of rising sea level? Is it possible? How are the planet's subsystems and the planet itself adapting to these new conditions?

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5) Explain how industries in a coastal or Great Lakes region would be affected by a change in coastal water levels. Examine as many different industries as possible — agriculture, recreation, tourism, chemical, etc. You are a worker in one of these industries and are concerned about rising seas or falling lake levels. Write a letter to your State Representative expressing your concern at the situation (possible causes, etc.) and the implications for your job and your area should sea or lake levels change.

Teacher Background Information:

Houghton, R.A. and Woodwell G.M. 1989. "Global Climatic Change." *Scientific American.* 260 (4) : 36 - 44.
Maps available showing possible sites for flooding in the U.S. if sea level rises. Article also presents good synopsis of overall global climate change. This includes the alleged causes such as greenhouse gases, particularly CO_2, and the evidence from ice cores and retreating glaciers.

References:

Houghton J. T., Jenkins, G. J., and Ephraums, J. J. (Editors). 1990. *Climate Change: The IPCC Scientific Assessment.* New York : Cambridge University Press.

Huser, V. (Editor.). 1988. *River Reflections. A Collection of River Writings.* Chester CT: The Globe Pequest Press.

Moore, P. and Hunt, G. 1990. *The Atlas of the Solar System.* New York: Crescent Books.

Skein, R. B. 1975. *Seascape and the American Imagination.* New York: Clarkson N. Potter, Inc.

VIDEO:

WGBH Foundation. 1990. "Only One Atmosphere." *Race to Save the Planet.* This program examines the consequences of an altered climate and its impact on different aspects of human life. Approximately 25 minutes in to the program it deals with the consequences of sea level rise and examines how one country has combated this problem in the past.

Fresh Water For A Warmer World

Climatologists predict that a 1.5 - 4.5°C warming of the Earth will probably occur by the middle of the next century. If warming trends continue as predicted, they will cause climatic conditions throughout the world to shift poleward, affecting each earth system in complex ways. In terms of fresh water, climatic changes would increase the demand in certain watersheds by increasing evaporation, changing humidity and precipitation patterns, and drying up some local supplies. Western and southwestern states may want to divert water from the Great Lakes to regions experiencing scarcity.

In addition, as the population of the world doubles during the next century, the demand for fresh water will increase dramatically. Every nation will be searching to expand the available fresh water resources. Since the early 1980s the southwest and high plains regions of the U.S. have proposed a water diversion from the Great Lakes that would supply them with much needed water.

The concepts studied in these activities include: *fresh water resources; climatic conditions' effects on fresh water resources; diversion of fresh water and global fresh water resources.*

Objectives: After completing this activity, each student will be able to:

1) identify the major water sources in the U.S. (Activity A).
2) explain where and how major cities obtain their fresh water supplies (Activity A).
3) explain how fresh water resources are used and managed in the western U.S. (Activity A).
4) explain how water is being diverted from the Great Lakes at the present time (Activity B).
5) describe some problems associated with diverting more water from the Great Lakes (Activity B).
6) analyze water practices in areas of water shortages to assess alternatives to bringing in more water (Activity B).
7) identify several nations in which population is increasing rapidly (Activity C).
8) describe the current sources of water for other nations (Activity C).
9) explain where these nations might locate additional fresh water resources (Activity C).

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

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10) describe the economic and environmental costs other nations might incur by providing additional fresh water supplies (Activity C).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3, 4, and 7. However, the following ESUs are covered in the Extensions — 1, 5, and 6. Refer to the Framework for ESE for a detailed description of each understanding.

Activity A: How are fresh water resources used in the U.S.?

The U.S. is fortunate to have abundant sources of fresh water. However, many people, especially in the western U.S., feel these water resources are mismanaged. . Their own water supplies are beginning to dwindle. Water development in the West is evolving to meet contemporary needs and values. In a region where droughts frequently deplete supplies to critically low levels, demand for water is rising rapidly. This demand is fueled by population growth and a growing recognition of the importance of preserving instream flows to protect the environment.

Changing climatic conditions will also influence fresh water supplies. Droughts may become more severe than those experienced in 1988 and 1991, which were particularly devastating in certain states. This condition has persisted for many years. People generally don't think about this resource until it is gone. When the faucet is turned on and nothing happens, THEN we worry about water supplies.

The purpose of this activity is to examine the location of fresh water resources and population centers, sources of fresh water and the role of increasing human population on fresh water resources.

Materials: blank 8 1/2" X 11" map of the U.S.; blue colored pencils; Atlas of U.S. or a CD-ROM with this information; library resources or computer data bases for information about major U.S. cities; Palmer Drought Severity Index sheet, attached; two plastic 2-liter bottles; one five or ten gallon aquarium; aquarium gravel; pinch clamp; four inches of rubber tubing; water; blue food coloring; a poultry baster.

Procedure:

1) Pass out a blank map of the U.S. and have the students draw in and label the following fresh water resources:

a) 10 natural fresh water lakes;
b) 10 rivers (one should be close to your school);
c) 10 constructed reservoirs (one should be close to your school);
d) 2 aquifers (underground sources of water).

[Define aquifer for students — "a permeable stratum or zone below the earth's surface through which ground water moves" (Hamblin, 1985, 498). When completed point out to students the scarcity of natural fresh water resources in the western U.S.]

2) Divide the class into pairs. Assign each pair a major city to study from the list below.

New York
Chicago
Salt Lake City
Denver
Las Vegas
St Louis
Orlando
Detroit
Bismarck
Nashville
Portland
Lake Havasu City
Los Angeles
Washington D.C.
Atlanta
Phoenix
San Francisco
New Orleans
Miami
Pittsburgh
Boise
Seattle
Boston
Your own city or town

3) Each student in the group should prepare answers for the following sets of questions.

a) What is the present population of this city? How much is the population expected to increase in the future? What are the sources for its present day water supply? How does the city generate electricity? How much does water cost a homeowner? a farmer? an industry?

b) **Every individual in this country uses at least 60 gallons of water every day, three-quarters of which runs through the bathroom.** How much water do people living in the city you are studying require in a day? How much water will these people require in the future?

c) Based on the geographic location of the city, and reports of impacts of climate change, what is likely to happen to the city's water resources in the next century? Has it experienced drought in the last few years? Where might this city obtain additional water and at what cost? How might the city be able to conserve water?

4) The largest source of fresh water in the U.S. is beneath the ground in aquifers. Half of the country's population and over 95% of people living in rural communities depend on this source of fresh water. What do you think would happen to these sources of fresh water if they were overexploited?

Observe the demonstration apparatus assembled by the teacher. On Figure 2 draw arrows predicting what will happen when water is withdrawn from the "well."

a) The demonstrator will pump water from the "well" several times. Describe what happens to the well water. What is happening to the aquifer to cause this change? In relation to cities near the coast, explain

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aquifer to cause this change? In relation to cities near the coast, explain how a rise in sea level, resulting from a change in climatic conditions, and a loss of groundwater are connected to each other.

b) Could aquifers located great distances from the coast become contaminated. How? What types of contaminants could affect the ground water supply? Could it affect the drinking water? How and what steps should be taken to prevent this from happening?

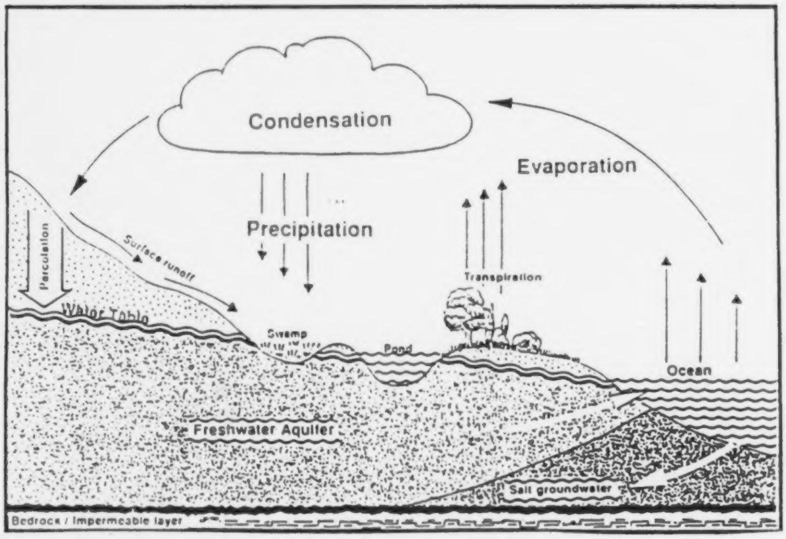
Condensation
Evaporation
Precipitation
Percolation
Surface runoff
Water Table
Transpiration
Swamp
Pond
Ocean
Freshwater Aquifer
Salt groundwater
Bedrock / Impermeable layer

Figure 1. - Fresh water aquifers located near coastal areas. (Source: Cape Cod Environmental Education Resource Center, 1990.)

[Assemble the demonstration apparatus as follows:

a) Cut off tops of two 2-liter plastic bottles to form cups about 15 cm deep.

b) Connect the cups by punching a hole near the bottom of each and inserting a rubber tubing section. The tubing should be flexible enough to fit tightly in the holes and wide enough so water can flow through easily.

c) Put a pinch clamp on the tubing to prevent water exchange from occurring before the demonstration is ready. Place the connected cups in an empty aquarium next to one side of the aquarium.

d) Fill one cup with clean water and one with blue colored water. Be sure to insert the baster into the clear water only.

e) Remove the pinch clamp. Add coarse gravel, sand or other filler around the cups so they are visible only to the demonstrator but not to the students. Students should only see the land, open ocean and a well on the surface.]

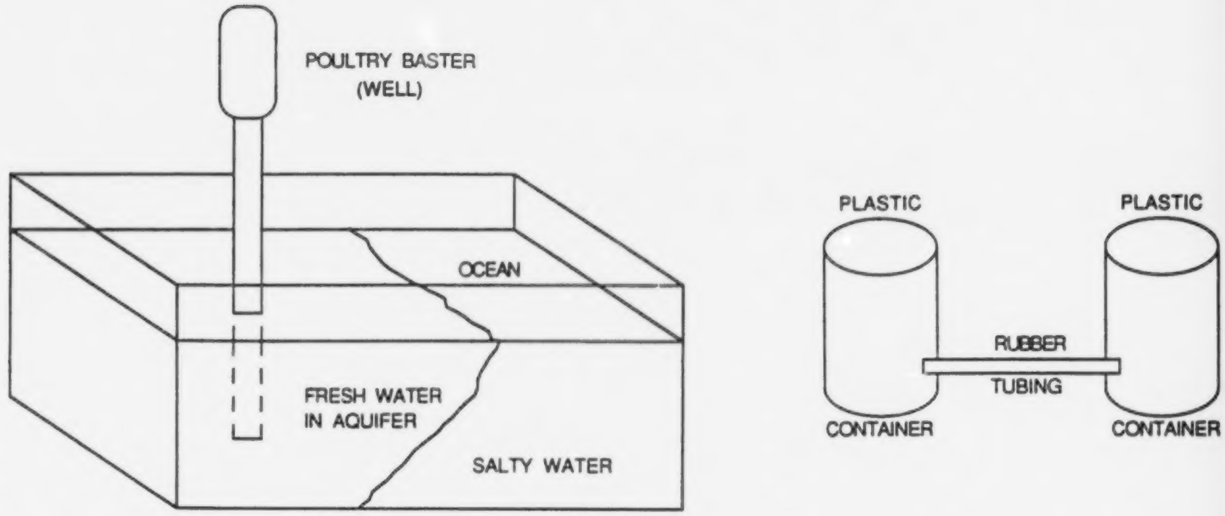

Figure 2. - Assembly of "aquifer system".

Evaluation:

Each student should produce a concept map which illustrates all the factors that influence human population and fresh water resources, supplies, and consumption. (Refer to a sample concept map in the high school activity "Tropical Deforestation: Causes, effects and implications".)

Activity B: Should Great Lakes water be diverted to serve western U.S. needs?

The Great Lakes have 20% of the fresh water available on the Earth, not including the ice in alpine and continental glaciers. Ninety - five percent of the fresh surface water in the U.S. is in the Great Lakes. The water is a tremendous resource for this country. The International Joint Commission (IJC) is a group of U.S. and Canadian scientists and policy experts who are responsible for advising federal governments from those two countries about management of this resource.

This activity is a role-play in which students will take a variety of viewpoints with different opinions about diversion of water from the Great Lakes for use in the Western U.S. (Many people do not realize that some water diversions already exist.) The students will present their viewpoints to a panel from the IJC as it tries to decide what to do about a proposed diversion.

Materials: wall map of North America; map of current water diversions of the Great Lakes; Great Lakes Diversion sheets, attached; description of different roles to play.

Procedure:

1) Randomly assign the students to 8 groups. Give each group the attached water diversion sheet to read and the map to examine. When they have finished, ask the students to identify the people that are affected by this issue. Discuss the problems for

these people with the students. Once they have identified the people involved, give each group a role to play. Each group should take about 15 minutes to read its role description and to prepare to present its viewpoint to the IJC. Each group should use no more than 5 minutes to give its presentation. Encourage the students to add any other information that they might deem necessary from the information in the water diversion sheet or from their own ideas.

The teacher or a group of students should play the role of the IJC. The question at hand is:

Should Great Lakes water be diverted to serve western needs?

[It may be helpful to write this question on the board so that students may keep it in mind. The students representing the IJC should read the attached global change fact sheet (How will Water Resources in the Great Lakes Region be Affected?). The IJC should listen to the different viewpoints and make recommendations about diversions. The role groups can then respond to this decision.]

Evaluation:

Each student writes a position paper that includes a personal decision about water diversion from the Great Lakes to western states. Make sure (s)he gives reasons for those decisions.

Further Discussion:

Determine the source of fresh water in your community and what plans your community has to expand this resource for the future when the water supply is running low.

Activity B is adapted from "*So you want water from the Great Lakes*" activity published by the Lake Michigan Federation, Chicago. Dan Jax, author.

Activity C: How do other countries meet their needs for fresh water?

At present, other countries around the Earth are becoming concerned with water quality issues. Some will face the depletion of their fresh water resources to an even worse extent than the U.S. In addition, many of these countries are facing a population explosion far greater than the U.S. Unfortunately, these nations may not have available to them a tremendous fresh water resource such as the Great Lakes. In the future they must be able to somehow increase their fresh water supply.

Materials: physical wall map of the world; computer database to locate information on other nations, or library resources on the necessary nations; World Atlas (5 - 10 copies) or one CD-ROM atlas.

Procedure:

1) Divide the class into groups, with at least 4 students in each group. Assign them one nation to study from the list below:

China
India
Ethiopia
Saudi Arabia
Eastern Europe countries — Poland, Hungary, etc.
Australia
Great Britain
Bangladesh
Mexico
Confederation of Independent States (C.I.S.)
Japan

2) Each student in the group should prepare answers for one of the following sets of questions:

a) What is the present population of this nation? How much is the population expected to increase in the future? What are the sources for present day fresh water supplies?

b) Based on the geographic location of the country, and on reports of impacts of climate change, what is likely to happen to the country's fresh water resources in the next century? What is the country's general level of contribution to climate change (example, amount of carbon dioxide added)?

c) In the future, where will this nation obtain fresh water supplies to meet the demands of an increasing population? How will they transport this fresh water to where it is needed?

d) How could the country pay the cost of increasing its fresh water supply? What environmental consequences might the country suffer as a result of increasing the fresh water supply?

3) Each group should make a presentation to the class lasting approximately 10 minutes on each nation. Individual students should answer their research question in approximately 3 minutes.

[Highly recommend that students take notes on each presentation so they can write their summary papers.]

Evaluation:

At the end of all the presentations each student should write a summary paper that specifies the nations in the future that will have the greatest population increases, identifies the potential sources of fresh water for these nations, determines which of these nations could face the greatest shortages, and describes the environmental impacts that might result from efforts to increase these nations' future water supplies.

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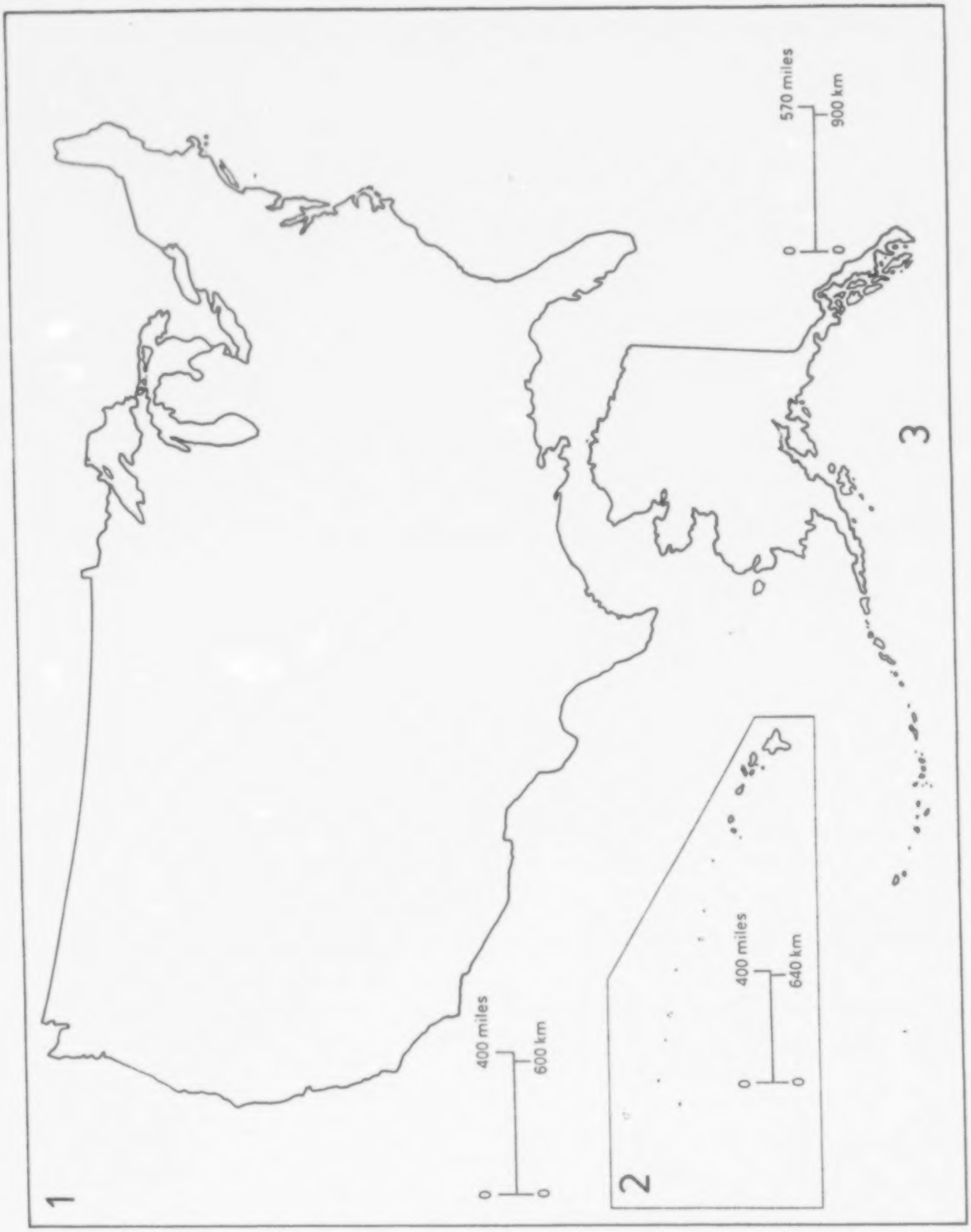

1
400 miles
600 km
0
0
2
400 miles
640 km
0
0
3
570 miles
900 km
0
0

Outline Map of the US

(Source: Lambert, *Earth Science on File*, 1988. © Diagram Visual Information Ltd.)

Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) was introduced in 1961 by Wayne C. Palmer of the National Weather Service in a paper titled "Meteorological Drought: Its Measurement and Classification." The index attempts to describe the length and severity of dry or moist spells by combining antecedent conditions with precipitation departure from normal and the influence of temperature on evaporation.

The PDSI is calculated weekly by the Climate Analysis Center of the National Weather Service for several specific applications:

- measuring the disruptive effects of prolonged dryness or wetness on water sensitive economies
- designating disaster areas of drought or wetness
- reflecting the general, long-term (several months) status of water supplies in shallow aquifers, reservoirs and streams.

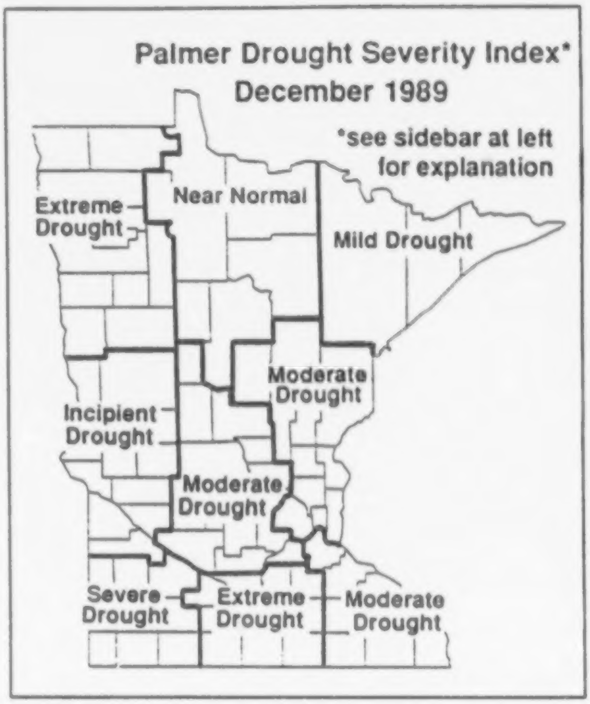
The PDSI is not generally indicative of the short-term (a few weeks) status of drought or wetness that frequently affects agricultural activities.

The PDSI is standardized so that a designation of "extreme drought" would have the same relative meaning anywhere in the nation.

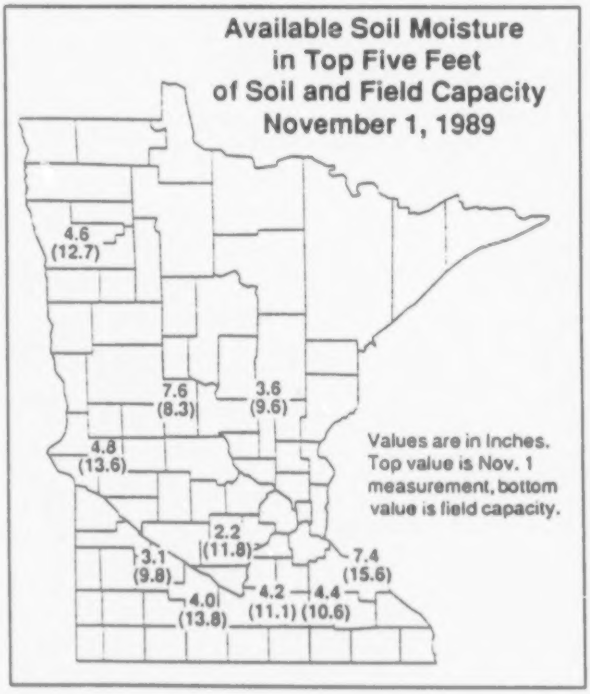
PDSI categories are arranged in the following order:
- extreme moist spell
- very moist spell
- unusual moist spell
- moist spell
- incipient moist spell
- near normal
- incipient drought
- mild drought
- moderate drought
- severe drought
- extreme drought

Palmer Drought Severity Index*
December 1989

*see sidebar at left for explanation

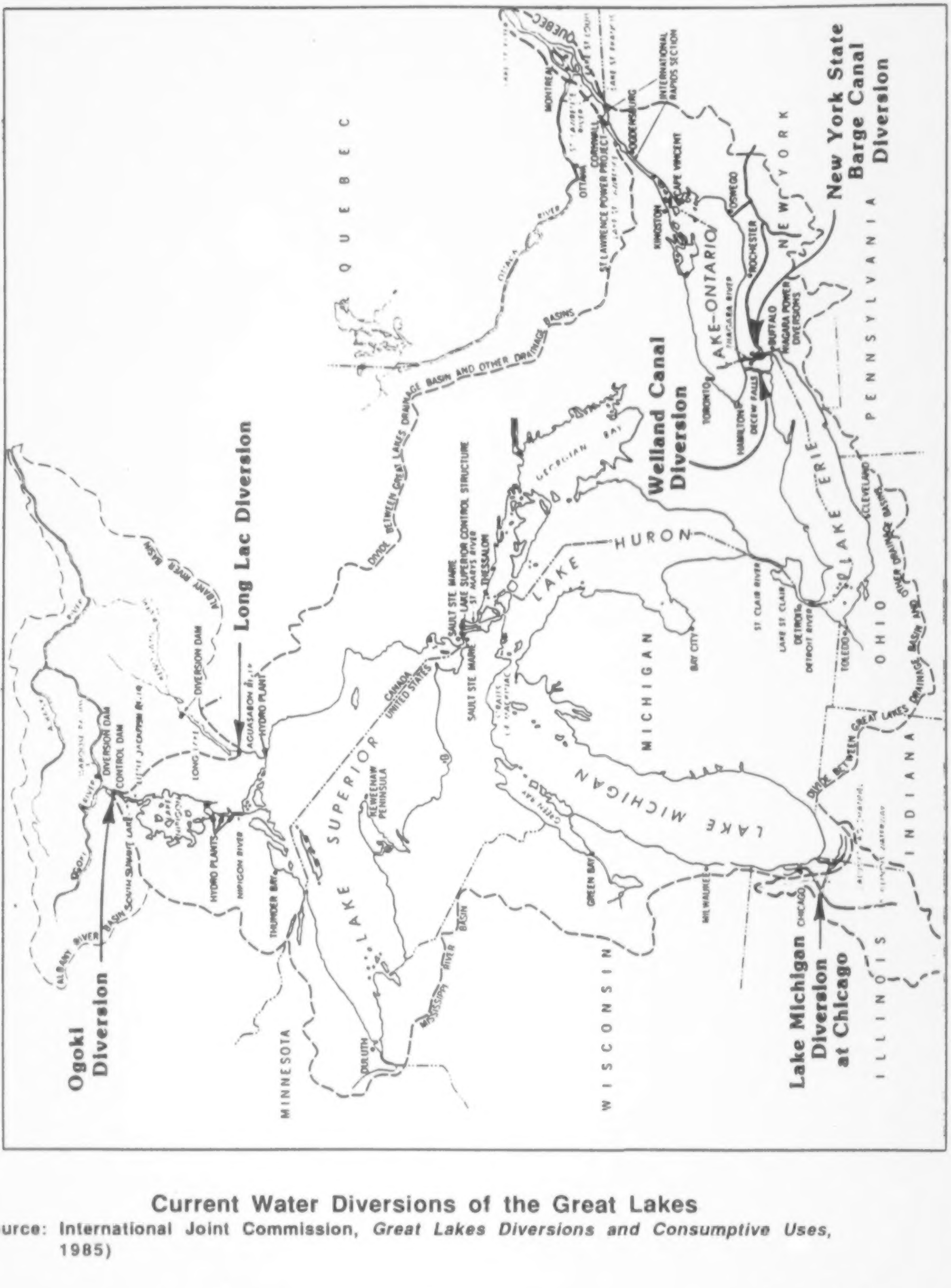

Near Normal
Extreme Drought
Mild Drought
Moderate Drought
Incipient Drought
Moderate Drought
Severe Drought
Extreme Drought
Moderate Drought

Available Soil Moisture in Top Five Feet of Soil and Field Capacity
November 1, 1989


4.6
(12.7)
7.6
(8.3)
3.6
(9.6)
4.8
(13.6)
2.2
(11.8)
3.1
(9.8)
4.0
(13.8)
4.2
(11.1)
4.4
(10.6)
7.4
(15.6)

Values are in inches. Top value is Nov. 1 measurement, bottom value is field capacity.

(Source: **Minnesota Department of Natural Resources, Division of Waters,** ***Water Year Data Summary 1989-1990,*** **1991)**


Ogoki Diversion
Long Lac Diversion
Welland Canal Diversion
New York State Barge Canal Diversion
Lake Michigan Diversion at Chicago
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
GEORGIAN BAY
MINNESOTA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW YORK
DULUTH
THUNDER BAY
SAULT STE MARIE
GREEN BAY
MILWAUKEE
CHICAGO
TOLEDO
CLEVELAND
BUFFALO
TORONTO
HAMILTON
ROCHESTER
OSWEGO
KINGSTON
MONTREAL
BAY CITY
KEWEENAW PENINSULA
CANADA
UNITED STATES
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS
ALBANY RIVER BASIN
MISSISSIPPI RIVER BASIN
ST LAWRENCE POWER PROJECT
INTERNATIONAL RAPIDS SECTION
NIAGARA POWER DIVERSIONS
LAKE SUPERIOR CONTROL STRUCTURE
DIVERSION DAM
CONTROL DAM
HYDRO PLANTS
HYDRO PLANT
NIPIGON RIVER
ST CLAIR RIVER
DETROIT RIVER
NIAGARA RIVER
DECEW FALLS

Current Water Diversions of the Great Lakes
(Source: International Joint Commission, *Great Lakes Diversions and Consumptive Uses*, 1985)

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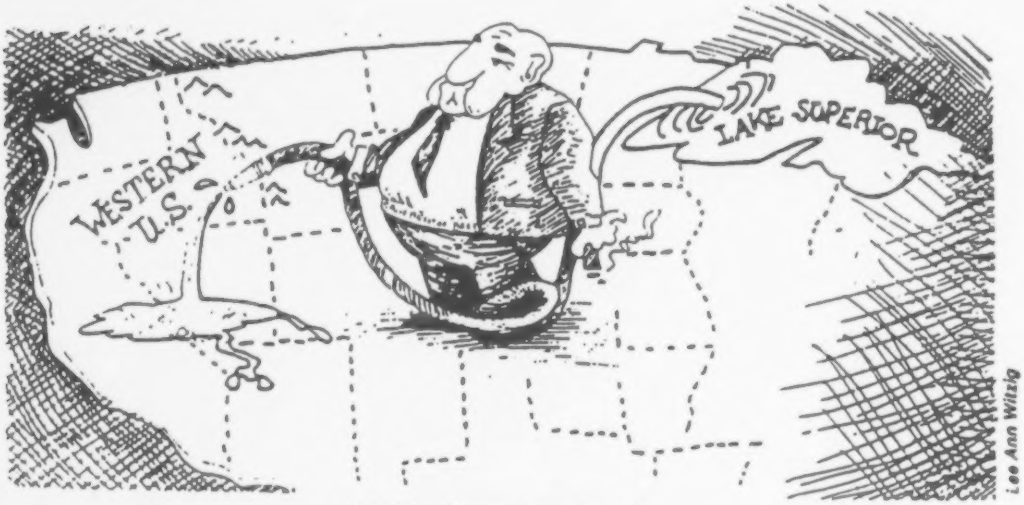
Great Lakes Water Diversion

by Dale Baker, Sea Grant Extension Director

The western U.S. is running out of water. Every year, 30,000 people move to Phoenix and the ground water table drops three feet. Every drop of the Colorado River has been allocated to supply the vast sagebrush belt extending from Denver to Los Angeles; from Salt Lake City to Tuscon. The grain belt plain states from South Dakota to Texas rely on groundwater stored in the Ogallalla Aquifer, which, at the current rate of consumption, will be gone by the year 2024. Thirsty westerners point to their solution: diverting water from the Great Lakes, which contain 20% of the world's fresh surface water. Water has become a political trump in the game of regional economic growth. The Great Lakes states, already suffering the reputation as the nation's "rust belt", are concerned about the western threat to their water resources. Where does the diversion issue stand today?

Figure 1 illustrates what most people don't realize: there are already five Great Lakes diversions. Canada has two diversions into Lake Superior. Constructed in the 1940s, the Ogoki and Long Lac diversions transport 11,200 cubic feet of water per second into Lake Superior. Both flows are used to generate electricity. The Welland Canal diverts 9,200 cfs from Lake Erie to Lake Ontario. Ships use the Canal to bypass Niagara Falls and hydroelectric power is produced at DeCew Falls. The New York State Barge Canal diverts 700 cfs from the Niagara River at Tonawanda, New York and returns it to Lake Ontario at several tributaries and the Oswego Canal. These are all intrabasin diversions because water is not lost from the Great Lakes Basin. The Chicago River diversion is the only diversion that transports water out of the Basin. Thirty-two hundred cfs are diverted from Lake Michigan down the Illinois River to the Mississippi River. The Chicago Diversion was built in 1848 to transport sewage effluent, increase navigability of the Chicago River, and to increase Chicago's water supply.



"A big lawn to water"

The total effect of all these diversions is to raise Lakes Superior and Ontario less than an inch, lower Lakes Michigan and Huron 1/4 inch, and lower Lake Erie by four inches. The 3,200 cfs being diverted out of the Basin is roughly equivalent to the flow of the St. Louis River at its mouth.

At present, more water is being diverted into the Great Lakes than out. And more water is lost from the Great Lakes by consumption than by diversion. Water is consumed when it is withdrawn or withheld from the Great Lakes for manufacturing or domestic use and is not restored. In 1975, Great Lakes consumption was 4,900 cfs, about 1 1/2 times the Chicago diversion. Consumption of Great Lakes water is projected to increase to 25,400 cfs by the year 2035 and would lower Lakes Michigan, Huron and Erie by 9 inches. Of course the fact that consumptive loss exceeds diversion loss is of little consolation to many because intrabasin consumptive losses benefit the Great Lakes economy. The point is that those Great Lakes citizens concerned that lowered lake levels will cause environmental and economic problems should realize that future drops in levels will most likely be caused more by their own consumption than by diversion.

Virtually every Great Lake state has or will soon pass legislation prohibiting any diversion without their permission. But since the federal government controls diversion of Great Lakes water, legislation cannot by itself prevent diversion. Anti-diversion legislation serves primarily to increase public awareness of the issue and to build political constituencies that are against diversion.

Great Lakes water is already protected by the 1909 Boundary Waters Treaty between Canada and the U.S. According to the treaty, diversions from all Great Lakes, except Lake Michigan, must be approved by the U.S. and Canada. Canada has adamantly opposed any Great Lakes diversions.

Lake Michigan is not protected by the 1909 Treaty. There have been proposals to double the size of the Chicago diversion. The added flow would be siphoned from the Mississippi River and transported west. Although there are no legal obstacles, there are formidable political obstacles to overcome. Canada has challenged the existing Chicago diversion for 60 years and recently succeeded in having the diversion flow reduced. A proposal to increase diversion would also receive strong opposition from Great Lakes states. Former Senator Percy has introduced Senate bill number 2026 which prohibits diversions out of the Great Lakes Basin without approval of each Great Lake State and the International Joint Commission, the Canadian - U.S. body that controls use of the Great Lakes. The legislation could make diversion by U.S. interests more difficult. The only Great Lakes support for diversion might come from shoreland owners who experience erosion problems during periods of high water levels. But as Canada argues, once a diversion begins, it's unlikely to be shut off when the water level is low or normal.

National Water Alliance co-chairman Senator David Durenburger warns that water has become a political rather than an economic commodity. Rational thinking may not necessarily guide water policy decisions. Durenberger believes diversion is a real threat to the Great Lakes. He suggests that the U.S. follow the Canadian example and become better stewards of the Great Lakes.

Canadian Politician

You are a politician from Canada. Your job is to protect the rights of Canada and Canadians and to preserve the use of water in the Great Lakes. Environmental groups are putting pressure on you to make sure that these rights are ensured.

The Boundary Waters Treaty of 1909 between the U.S. and Canada guarantees that any decision about diversion of water from the Great Lakes must have the approval of both governments. The problem is that Lake Michigan is not on the Canadian border and is not covered by the treaty.

Mayor of a City in the Southwestern U.S.

Your city has doubled in size in the last 20 years and because of the beautiful weather and scenery there, it is expected to double again in the next fifteen years. The water supply is getting low. There are no other supplies of water in your area. You and your Planning Commission somehow must figure out a way to ensure a sufficient water supply for your growing population.

You can point out that the expected increase in consumption of water from the Great Lakes by the Great Lakes states themselves over the next 20 years will lower lake levels more than diversion ever would.

Farmer from the High Plains

Eighty-five percent of the water used in the United States is used by 17 growing western states. Most of this water is used by farmers for growing food and raising livestock. The Ogallala aquifer has supplied you with water for many years, but you have had to drill deeper and deeper wells to get the water out. Someday the aquifer will dry up. With the expected increase in population, the demand for food will also increase. You feel you must have water from the Great Lakes to meet this demand.

Economist

If the water levels of the Great Lakes were lowered, the value of shoreline property could increase because it would be less likely to be flooded and eroded during storms. It is difficult to say how recreation around the lake would change. Fishermen may not visit the lake as much because fish habitat may be reduced, hence fewer fish. This could offset the possible increase in property values. Marinas would have difficulties with their dock facilities if the water is lower. This would further discourage fishing. Ships would have greater difficulty getting into and out of ports and so this may affect the economy of the region.

In the southwest and high plains, the economy is dependent upon water. With projected increases in population, the water supply will be severely strained. The overall population increased 18% in all the west from 1975 to 1980.

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Great Lakes Politician

You must make sure that the rights of the people of the United States are preserved. Most of the Great Lakes states either already have or will soon have laws that guarantee that no water will be diverted from the Great Lakes without the state's permission. You also know that water can be diverted from Lake Michigan without Canada's permission, something that is needed for diversion from the other Great Lakes. Industries and ship owners are putting pressure on you to ensure an adequate water supply for their activities.

Great Lakes Marina Owners

With lower lake levels that result from diversion, your dock facilities will have too little water to service most boats. You must either invest a great deal of money to build new docks or to dredge the old ones to make the water deeper or go out of business. You are also concerned that fishermen may stay away from the lake because lower lake levels may destroy fish habitat and result in fewer fish.

Great Lakes Ship Owners

If water is diverted from the Great Lakes, the lake level will be lower. Your ships will have great difficulty getting into and out of harbors. You may have to load less cargo on your ships so that they will ride higher in the water, or build a whole new fleet of ships with shallower drafts. The result will be higher costs and lower profits.

Scientists

You are really concerned because lower lake levels will cause wetland areas along the shores of the lakes to be drained. Wetlands are very important to the lakes. They act as a filter for sediment and certain pollutants that enter the lakes. They also provide a sheltered place for fish to spawn and for many other organisms to reproduce and live. Draining the wetlands could result in fewer fish and other organisms and lower water quality.

Extensions:

1) "Water, water everywhere, nor any drop to drink" — is a line from a poem (The Rime of the Ancient Mariner) written by Samuel Taylor Coleridge. He wrote this poem about the sea, and the quotation means that even though seventy-five percent of the Earth's surface is covered by sea, it is not directly utilized for drinking. Try to locate some other forms of literature or media that document the importance of water to all living creatures. This material should be procured from a non-science source. For example, the writings of Sigurd Olson, Aldo Leopold, poetry of Robert Frost, music of Gordon Lightfoot, etc.

2) Rivers, and the Great Lakes particularly, created a special culture — the explorers and the voyageurs. Describe how these people interacted with the environment and their impact on the historical, cultural and environmental aspects of the Great Lakes region. Try to locate the writings of one voyageur and read the descriptions of the environment of the Great Lakes. (Refer to books by Gilman and Havighurst.) Compare it to the present state of the environment.

3) The Colorado river has changed dramatically over its lifetime. Humans in the last century have altered this river extensively. Study the Colorado and how it has been changed to meet the growing demands of the western states. Read "Down the Colorado," a diary of the first trip through the Grand Canyon by John Wesley Powell. Powell describes the local environment and geology of the river. Use this, Cadillac Desert written by Reisner, or a similar source to investigate the changes that have occurred to this magnificent river.

4) Trace the role that water played in the development of planet Earth. At what point in the evolution of the planet did water first appear? How important was this liquid to the evolution of life on the planet? Is the water that you drink today the same that appeared on the planet millions of years ago?

5) What impact could a change in global temperature and climatic patterns have on the distribution of water and the hydrologic cycle? Which countries would be most/least influenced by this alteration in water distribution? Give reasons for your answers. Do you think that a change in the abundance of water resources could affect the political system in a country? What affect could this have on the political situation between countries — could it lead to greater cooperation or conflict between countries?

6) Is the planet Earth the only planet in our solar system that has water? What are the other planets? Is the water present on these other planets in a solid, liquid or gaseous state? If water quality or quantity becomes a problem on this planet, would it be feasible to import this natural resource from other planets?

7) In recent years, various scientists have discussed the feasibility of cutting ice chunks from the edges of the Antarctic and Arctic ice sheets and floating them to the nearest countries. How feasible is this project? Do we possess the technology to

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perform this successfully? What influence could this have on the ecosystems of these areas? Support your answers.

Teacher Background Information:

Carrier, J. 1991. "The Colorado, A River Drained Dry." *National Geographic.* 179 (6) : 4 - 34.

An excellent historical account of the Colorado River, a resource under severe stress. This article documents the 1922 Colorado River Compact and the division of water between different western states. It also examines the present situation of this water appropriation and the impact increasing human population will have on this situation. Excellent photography aids in visualizing the present situation.

McDowell, J., and Woodbury, R. 1991. "A Fight Over Liquid Gold." *Time.* July 22, 20 - 26.

An excellent article again dealing with the Colorado River, but is relevant to any water diversion project. This deals with the people in the region and their needs and desires for this 'liquid gold'.

Thompson, J. 1991. "East Europe's Dark Dawn: The Iron Curtain Rises to Reveal a Land Tarnished by Pollution." *National Geographic.* 179 (6) : 36 - 69.

This article documents the serious environmental problems cloaked by the Iron Curtain during Communist Rule in the Eastern Bloc countries. While the report includes different environmental problems, water quality is dealt with as one of the more serious consequences of unregulated industrial development.

Powell, J. W. 1869. "Diary of the First Trip Through the Grand Canyon." In *Down the Colorado.* 1988. New York: Arrowood Press, 166 Fifth Ave.

This book is an excellent production with magnificent photographs of the Colorado River as it carves its way through the Grand Canyon. Interspersed with original sketches from Powell's trip are more recent photographs, and the writing quoted from the diary create an image of what these first travelers experienced on this once majestic river.

References:

Babbitt, B. 1991. "Age-Old Challenge: Water and the West." *National Geographic.* 179 (6) : 2 - 3.

Barber, K. L. *Alert on the Great Lakes Diversions.* Lake Erie Basin Committee: Painesville, Ohio. 6.

Cape Cod Environmental Resource Center. 1990. *Groundwater Resource Guide.* V1 (1). West Barnstable, MA 02668: Cape Cod Community College.

Frederick, K. D., and Kneese, A. V. 1984. *Competition for Water.* Washington D. C.: Resources for the Future. Reprint 216. pp. 108.

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International Joint Commission. 1985. *Great Lakes Diversions and Consumptive Uses.* A Report to the Governments of the United States and Canada under the 1977 Reference.

Lambert, D. 1988. *Earth Sciences on File.* New York: Facts on File, Inc.

Lathem, E. C. (Editor). 1979. *The Poetry of Robert Frost.* New York: Holt and Company.

Minnesota Department of Natural Resources. 1991. *Water Year Data Summary, 1989 and 1990.* St. Paul: MNDNR, Division of Water. May.

Moore, P., and Hunt, G. 1990. *The Atlas of the Solar System.* New York: Crescent Books.

Nichols, A. B. 1991. "Western Water Development in Transition." *Water Environment and Technology.* August. 63 - 68.

Reisner, M. 1986. *Cadillac Desert.* New York: Penguin Books.

Solley, G. C., and Steinbaugh, E. (Editors). 1981. *Moods of the Sea. Masterworks of Sea Poetry.* Annapolis, MD: Naval Institute Press.

Yee, P., and Lloyd, J. 1984. *Great Lakes Water Levels.* Environment Canada, Ottawa.

VIDEO:

WGBH Foundation. 1990. "Only One Atmosphere." *Race to Save the Planet.* Thirty-eight minutes into the program is an excellent five minute segment concerning the allocation of water from the Colorado River and the influence of global warming. Annenberg/CPB Project, The WGBH Science Unit in Association with Chedd-Angier, Film Australia, The University Grants, Commission of India, Gujarat University/EMR.

THE OZONE HOLE:

Public Response to a Global Threat

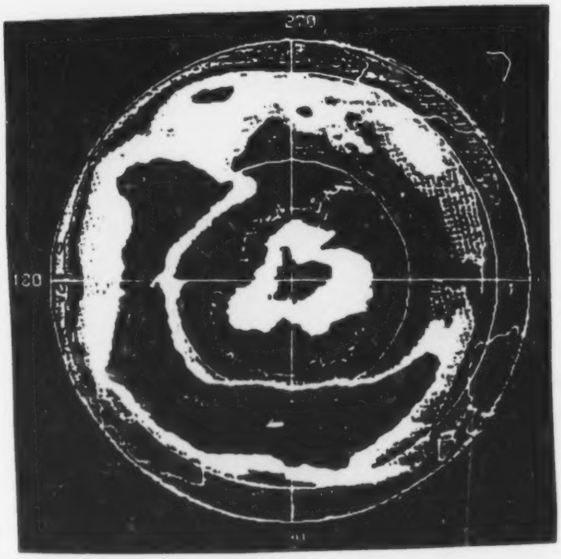


Figure 1. - The size of the ozone hole in 1987 was almost as large as the entire Antarctic continent. The latest data show that the ozone hole has grown substantially in five years. If an area of similar size opened over the northern hemisphere it would place at risk a large proportion of the population of North America, Europe, the Middle East, China, India and the Confederation of Independent States (formerly the U.S.S.R.). (Source: NASA, Greenbelt, MD.)

Ozone (O_3) is a gas naturally present in small amounts at ground level, but far more abundant in the stratosphere. However, ozone represents only a tiny fraction of the total atmosphere. If all the ozone in the stratosphere were compressed into a band of pure gas at surface temperatures and pressures its total thickness would be only 3 mm, about as thick as three dimes. Yet, ozone absorbs certain kinds of ultraviolet radiation that are potentially harmful to living things. Life on Earth is possible in part because of the protection afforded by the stratospheric ozone layer (Figure 2).

Objectives: After completing this activity, each student will be able to:

1) trace the history of the impact humans have had on the ozone layer (Activity A).
2) define ozone gas and describe its characteristics (Activity A).
3) explain the harmful effects of CFCs on the ozone layer (Activity A).
4) identify the measures which can be used to protect the ozone layer (Activity A).
5) identify the ozone depletion information that the public should know (Activity B).
6) develop a public health message which communicates effectively the threat of ozone layer depletion (Activity B).

Earth Systems Understanding (ESUs): This activity concentrates on ESUs 2 and 3, however, the following ESUs are covered in the Extensions — 1, 4, 5, 6, and 7. Refer to the Framework for ESE for a full description of each understanding.

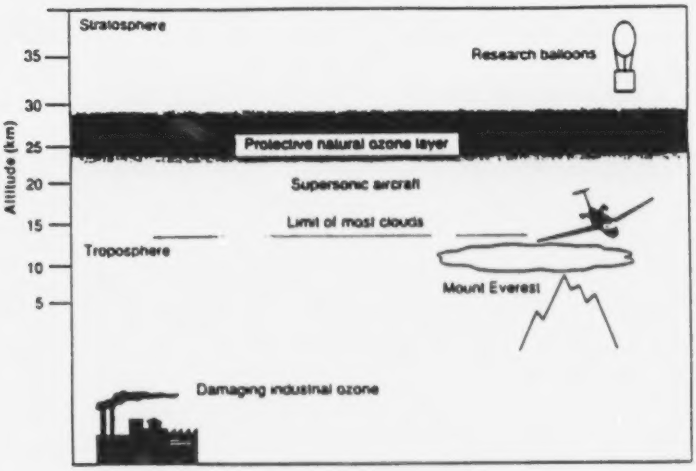


Figure 2. - **The vertical distribution of ozone in the atmosphere. (Source: Atmospheric Environment Service, *Understanding Atmospheric Change*, 1991.)**

Activity A: Discovering the facts about the ozone layer and CFCs.

Concerns about the ozone layer first surfaced in the late 1960s, when plans for high-flying supersonic transports raised fears about the possible destructive effects from the exhaust gases of these aircraft. However in 1985, scientists from the British Antarctic Survey published data which sent shockwaves throughout the scientific community. Their observations showed that for the period from September to mid-November ozone concentrations over Antarctica declined by 40% compared to levels in the 1960s. These results of a depletion in the ozone layer were confirmed by both U.S. and Japanese scientists.

In this activity students will participate in an ozone hole game in order to understand ozone gas, how it is being destroyed, and what can be done to preserve the ozone layer. The concepts studied in this activity include: *ozone gas, CFCs, stratosphere, ozone depletion, and its consequences on human health.*

Materials: ozone depletion information sheet; ozone hole game board; ozone hole questions (white, red, and blue); individual game pieces (coins or other small objects).

Procedure:

1) Distribute the ozone depletion information sheets to the students and allow them some time to read it.

2) Divide the class into groups of 4 or 5 students. Each group should have an ozone hole game board, a set of ozone hole questions, and four or five game pieces to move around the board.

3) The object of the game is simply to be the first student in the group to reach the Antarctic ozone hole in the middle of the game board. Along the way students will have to answer questions about ozone and CFCs.

4) There are 3 levels of questions which students may **self select.** *White = least difficult; Red = moderately difficult; and Blue = most difficult.* The number of spaces students may advance upon a correct answer depends on the difficulty level of the questions which they choose. The following is a suggestion for the number of spaces the students may advance and possible penalties for wrong answers.

White level questions:	Correct answer =	advance	1 space
	Incorrect answer =	no penalty	
Red level questions:	Correct answer =	advance	2 spaces
	Incorrect answer =	return	2 spaces
Blue level questions:	Correct answer =	advance	3 spaces
	Incorrect answer =	return	3 spaces

***Players may not select a Red or Blue level question if their game piece is at "Start"**

5) When a player selects the level of question to answer, the person to the left picks up the top card from that level and reads the question. If the player answers correctly, make sure everyone in the group hears the answer. If the player answers incorrectly, then reader tells the entire group the correct answer. Whether answered correctly or incorrectly, the question card is returned to the bottom of the stack.

6) Continue to play the game until a student reaches the finish. It is possible to go through the questions several times until a winner is found.

[A great deal of learning will take place by increasing the students' listening skills if the questions are repeated.]

7) After every group has a winner a championship match can be played between the winners of each of the groups.

[It would be helpful for the teacher to produce an overhead transparency of the game board so all students can follow the championship match as the teacher reads the questions and moderates this game.]

8) Following the game, distribute the ozone game cards marked with an asterisk to the groups. Allow them time to produce a concept map on ozone depletion on a sheet of paper 8 1/2" x 11" (or a transparency of the same dimension). If using the paper, copy it onto a transparency. Display the different concept maps on the screen and ask the students for any similarities or differences between the maps.

Activity B: What can the public do to prevent ozone layer depletion?

The depletion of the ozone layer can only be solved by widespread public response to this global threat. The scientific evidence is very clear on the negative impact that CFCs have on the ozone layer. However, communicating this information to the public so that people respond by taking action to reduce CFC usage is a difficult task. The purpose of this activity is to have students use the facts which they learned from the "Ozone Hole Game" and develop public health messages which would help people learn how to protect themselves and the ozone layer.

Materials: video camera; VCR; video film; TV monitor; hair sprays; pictures of refrigerators and vehicle interiors; shaving cream; stick deodorants; foam insulation.

> [If equipment is unavailable students could do a simulated live news broadcast as an alternative.]

Procedure:

1) Ask the students to bring to class some everyday products (or pictures of them) that they use which contain CFCs and some 'ozone-friendly products'. Discuss with the students the importance of these products to the atmosphere in light of the information learned in Activity A. Ask them the question: why are certain products, such as hair sprays, now considered 'ozone-friendly'? After the discussion, ask the students "how can the public, and that includes us, prevent ozone depletion?"

2) Divide the class into groups of 2 - 4 students. Instruct the groups that they are to prepare a one minute public service announcement for television which would explain the threat of ozone layer depletion to the public. Emphasis of the public service announcement should be to persuade the public to take action on their own to prevent the threat.

3) Write on the board or an overhead transparency the five criteria on which their public service announcement will be graded —

   a) originality and creativity.
   b) factual content and accuracy.
   c) visual presentation.
   d) length of time (public service announcement should be within a few seconds of 1 minute.)
   e) the persuasiveness of their public service announcement.

4) A written script for the public service announcement should first be prepared by the group and shown to the teacher for suggestions and approval.

5) The students should prepare an initial public service announcement which would be videotaped but not graded. At this time the students should edit and make any changes necessary for their final product.

6) The public service announcement should be videotaped again. The second videotaping will be graded based on the above criteria, and all the videotapes should be shown to the class.

7) Ask the students how their public service announcement would change if it were broadcast on radio.

> [The scripts for the public service announcements should be submitted to the school office with the suggestion that they be read over the PA system as part of the morning announcements. This would be an excellent way to get your students recognition, but more importantly it would make students in the rest of the school aware of their role in protecting the ozone layer. It would also be interesting to have the students conduct a survey a few days following the announcement (s) on the PA system to determine if it has influenced students' behavior with these products.]

Extensions:

1) "Earth is unique, a planet of rare beauty and great value". Consider this statement in the light of ozone depletion and the possible implications for all life on the planet, not just humans. You should begin by examining the effects of this environmental problem on the area that it was first discovered and its implications for the wildlife in this region.

2) Ozone depletion will influence all the systems on Earth. How will it impact these systems (water, land, ice, air and life)? Produce a concept map to show how you would interpret these impacts.

3) What happens to CFCs when they are recycled? How are they neutralized? Is there any way these CFCs could be used? Some scientists speculate that Mars may be needed as a colonization planet if we continue on our present course of population growth and resource utilization. However, before humans can move there on a mass scale the planet must be habitable. At the moment Mars is extremely cold — equatorial summer temperatures range from -111°C just before sunrise to a high of 26°C at noon. Annual polar temperatures rarely exceed -123°C. What changes need to occur on Mars to allow it to become habitable for humans? What role could CFCs play in this? Do you think this idea is feasible?

4) As a result of stratospheric ozone depletion, certain areas of the world are likely to have increased amounts of UV radiation penetrating to ground level. What type of pigment in the skin of humans helps to reduce the impact of UV light on it? If ozone depletion continues, will humans be able to adapt to increased UV exposure without artificial means? Examine the present situation in Australia. What has happened in recent years and have people altered their lifestyle as a result of this change? How?

5) Some scientists inform the President of the United States that the northern hemisphere is suffering massive ozone depletion. Even the fact that production of the

CFCs has ceased is not helping the situation. The gradual accumulation in the atmosphere of these gases has caused increased levels of radiation to be detected at all the world monitoring stations on the North America continent. The President decides to call his top scientific advisor. This person has the training, knowledge and ability to inform the President of the actual situation. However, the scientific advisor decides to bring a variety of people with different careers into the White House to tell the President how ozone depletion has impacted their career, their business, etc.. You are one of these people. Select one career (it does not have to be a scientist, it could be a doctor, a fisher, a sailor, etc.) and describe in writing (or any other form) what you would tell the President.

Teacher Background Information:

Lemonick, M. D. 1992. "The Ozone Vanishes." *Time*. February 17, 60 - 63.
This is an excellent article which details the history of the ozone hole, its present status and impact in Antarctica and Australia. It also documents the chemical reaction involved in the degradation of ozone. (This issue of *Time* also contains another ozone article by Philip Elmer-Dewitt, cited in references.)

Roan, S. 1989. *Ozone Crisis.* New York: John Wiley & Sons Inc.
A very readable account of the discovery and evolution of the ozone hole, the politics involved in facing the crisis, and the importance of scientific research as the basis of action.

World Meteorological Organization. 1992. *WMO and the Ozone Issue*. Geneva.
A booklet available from the American Meteorological Society, produced by the WMO, with excellent graphics documenting the past and present levels of ozone. Also details the various protocols that were signed by various countries and their significance to ozone depletion. (For a full list of available WMO literature and prices, write to American Meteorological Society, 45 Beacon St., Boston, MA. 02108-3693.)

University Corporation for Atmospheric Research/National Oceanic and Atmospheric Administration. 1992. *Our Ozone Shield.* Boulder, CO.
An excellent booklet documenting the history of the ozone threat to the planet. It follows the response of the American and other governments to this environmental problem. This report has wonderful graphics and is a very readable account of the ozone depletion process. It is the second in a series of *Reports to the Nation on Our Changing Planet* by this organization. Copies are available from the UCAR Office for Interdisciplinary Earth Studies, PO Box 3000, Boulder, CO. 80307-3000.

OZONE GOING...GOING .....GONE!!!!!!!!!

What is ozone? Ozone is a gas composed of three oxygen atoms with an unstable molecular structure. Ozone is spread throughout the atmosphere, eighty percent is located in the upper part — the stratosphere — between 15 and 40 km above the earth's surface. The highest concentrations of the gas occur at an altitude of about 25 km. Ozone is very widespread. If it were concentrated it would measure only 3 mm in thickness, about the same as three stacked dimes. It is the ability of this gas to absorb ultraviolet (UV) light that makes it so significant to all life on Earth.

Ozone also affects the movement of air currents across the earth and the atmosphere's temperature. By absorbing infrared radiation, ozone regulates the flow of heat energy in the atmosphere. Any disturbance in the concentration and distribution of ozone could have a significant effect on this process. Therefore, it is possible that ozone depletion, deforestation and continued high levels of greenhouse gas emissions, could greatly impact the earth's climate, resulting in increased global warming.

How does ozone form?

Intense UV radiation in the upper atmosphere cause oxygen molecules (O_2) to break their bonds, releasing oxygen ions. These free ions combine with intact oxygen molecules, creating ozone. Ozone is created down through the atmosphere. Consequently, most of the UV radiation is gone by the time it reaches the Earth's surface. This protects living organisms below the lower atmosphere from this potentially harmful radiation.

The Discovery of the Hole.

Many scientists had begun to suspect that chlorofluorocarbons or CFCs, would react with the ozone in the atmosphere, thereby destroying it. The discovery of an ozone "hole" over the Antarctic in 1985 confirmed their worst fears. Since then this "hole" has been monitored continually and is increasing. The "hole" is an area where the amount of ozone in the stratosphere is seriously depleted in the south hemisphere springtime (Sept. - Nov.). Ozone is an unstable molecule and readily combines with other atoms in the atmosphere. Chlorine and bromine from the CFCs combine with one of the oxygen atoms to form chlorine monoxide and bromide monoxide, respectively. These new molecules then eventually combine with other free oxygen atoms producing new oxygen molecules and releasing the chlorine and bromide atoms. The free atoms can then continue on with their devastation of further ozone molecules. The new oxygen molecules are not capable of shielding the earth's surface from ultraviolet light, allowing harmful radiation to penetrate through the atmosphere. One of the more frightening aspects of this process is that the chlorine and bromide atoms can persist for up to 100 years or more, creating havoc in the upper atmosphere.

Chlorofluorocarbons are found in refrigerants, air conditioning units and some aerosol sprays, a part of everyday life in our industrialized society. However, if the gases are more prominent in the developed countries in their manufacture and use, why did the ozone "hole" first appear over the Antarctic?

The formation of the "hole" required at least two components — CFCs and extreme cold temperatures. The Antarctic, the coldest place on Earth, was the most probable location for this process to occur. During winter, the severe low temperatures create a winter vortex — a spirally spinning mass of air — that speeds up the destruction of ozone. CFCs were transported to this location on the air currents of the upper atmosphere. However, as the southern hemisphere spring approached and the air temperatures increased, the vortex lost it's tight shape. The area inside the vortex increased and eventually spread, resulting in a hole the size of Alaska over the Antarctic continent. This became an annual occurrence and when the hole was discovered 40% of the ozone was missing. This event is having some impact on the wildlife of Antarctica and Southern South America.

Australians were issued warnings by their health department on the effect of this type of radiation and the precautions to take. A country where the population has twice the normal world average for skin cancer cannot afford to take risks. However, like most countries, Australia was not prepared for this invisible threat. For two day, in December 1987, ozone levels dropped by 12% over parts of the country, exposing every living organism to high levels of radiation. This was caused by the breakup of the winter vortex over the Antarctic.

What about the other cold area in the world — the Arctic? In 1990, a drop of 7% was found to exist there, a frightening prospect if it were to spread — as the northern hemisphere is much more densely populated than the southern hemisphere. Recently, ozone levels in the northeastern U.S. exhibited a decrease.

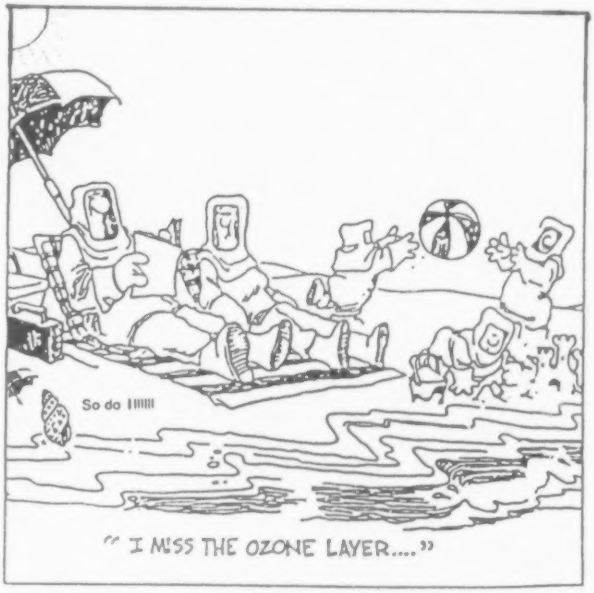
Substitutes for CFCs.

CFCs were first produced, on a mass scale, after World War II. Production steadily increased up until the seventies. They were used in commercial and residential refrigeration and air conditioning, mobile air conditioners, production of plastic foam and foam insulation products, flexible polyurethane foam, rigid polyurethane foam, sterilizers, solvents, and halons use in fire extinguishers.

It became harder for industries and governments alike to ignore the problem CFCs were causing. The McDonald Corporation (the largest fast food chain in the world) toward the end of 1987, announced it would discontinue its use of polyurethane foam containers within 18 months. Even though less than 2% of the total United States' consumption of CFCs was from food packaging, McDonald's effort helped to make great strides in raising general public awareness about this environmental issue.

But CFCs were not used only in the United States and banning the use of CFCS there would not solve the problem. An international effort was needed. In September of 1987, delegates from 43 countries gathered in Montreal to develop the Montreal Protocol on Substances that Deplete the Ozone Layer. The participants agreed to a halt on consumption and production of CFCs at 1986 levels by 1990; a 20% reduction by 1994; and an additional 30% by January 1, 1999. Following this meeting, Du Pont, which produced one fourth of the world's CFCs in 1988, agreed to phase out production as substitutes became available.

Health risks have been linked to increased exposure to UV radiation. Since the ozone layer filters out UV rays from the sun, reduction in the layer allows more of the rays to reach the earth. Reports have stated that for every 1% drop in ozone 2% more ultraviolet light reaches the earth's surface and raises the incidence of skin cancer by 5 - 7%. UV radiation can also cause cataracts, weaken the immune system, damage crops and disrupt the reproduction of plankton, the basis of the marine food chain.


So do IIIIII
" I MISS THE OZONE LAYER...."

Adapted from a cartoon in the Kansas City Star, 1988.

START

1840
Ozone Discovered

1880
U-V-Ozone Cutoff Discovered

1928
CFCs Invented

1950s
CFC Usage Grows

1957
The International Geophysical Year

1970
Nitrogen Ozone Chemistry

1974
Chlorine Ozone Chemistry

1979
CFC Aerosol Ban

1980s
CFC Usage Grows Again

1985
Ozone Hole Discovered

1986
National Ozone Expedition

1987
Montreal Protocol Signed

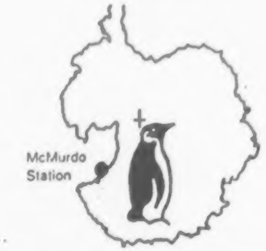
1988
Ozone Depletion not Confined to Antarctica

1990
Montreal Protocol Amended

1990
U.S. Clean Air Act Amendments

1992
U.S. steps up timeline to ban CFCs

Finish



ANTARCTIC OZONE HOLE

OZONE HOLE GAME BOARD

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[* denotes questions answered in the Ozone depletion fact sheet.]

White Level Questions:

correct answer = advance 1 space
incorrect answer = no penalty

Question: What is the chemical formula for ozone?

Answer: O_3

Question: What does the abbreviation UV represent?

Answer: Ultra-Violet

*

Question: What chemical did CFCs help to replace?

Answer: Ammonia

*

Question: What natural process helps produce ozone in the atmosphere?

Answer: Sunlight

Question: What does the abbreviation IGY represent?

Answer: International Geophysical Year

Question: In what year did IGY take place?

Answer: 1957

Question: How thick would the ozone layer be if it was at surface temperatures and pressures?

Answer: 3mm or 3 dimes

*

Question: The use of CFCs was first banned in what type of product?

Answer: Aerosol or spray cans

*

Question: In what year was the ozone hole over the Antarctic discovered?

Answer: 1985

Question: What famous space craft has measured ozone levels?

Answer: Space Shuttle

*

Question: What percentage of all the ozone is found in the stratosphere?

Answer: 80%

*

Question: Over what area of the Earth is the ozone layer naturally thin?

Answer: Equator

*

Question: During what month do ozone levels begin to decrease over Antarctica?

Answer: September

Question: How many sites around the world monitor CFCs emissions?

Answer: 7

*

Question: In what season of the year does the ozone hole develop over Antarctica?

Answer: Spring

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Question: What state in the U.S. is about the same size as the Antarctic ozone hole?

Answer: Alaska

Question: Where on the earth is chlorine produced naturally?

Answer: Oceans or hydrosphere

Question: What natural event deposits aerosols into the stratosphere?

Answer: Volcanic eruptions

Red level questions:

correct answer = advance 2 spaces
incorrect answer = return 2 spaces

Question: What layer of the atmosphere contains the ozone layer?

Answer: Stratosphere

Question: What type of winds circulate ozone in the atmosphere?

Answer: Stratospheric winds

Question: In what year were CFCs invented?

Answer: 1928

Question: For what use were CFCs primarily invented?

Answer: Refrigerants

Question: How much does UV radiation increase naturally for every 2-3° of latitude southward across the U.S?

Answer: 1%

Question: When building a home, how might CFCs be used?

Answer: In production of insulation Materials

Question: What company was the largest producer of CFCs?

Answer: DuPont

Question: What percentage of the ozone layer was found depleted over the Antarctic in 1985?

Answer: 40%

Question: What 2 chemical elements are involved in the destruction of the ozone layer?

Answer: Chlorine and Bromine

Question: What organization held a conference that resulted in the Montreal Protocol?

Answer: United Nations

Question: What does the abbreviation AAOE represent?

Answer: Airborne Antarctic Ozone Experiment

Question: What act by Congress requires reports on the ozone layer?

Answer: Clean Air Act of 1990

Question: Name a safer substitute form of CFCs.

Answer: HCFC or CFC-502

Question: When was the decrease in ozone first detected over the Arctic region?

Answer: 1970

Question: What was the first year that atmospheric chlorine input was reduced from the previous year?

Answer: 1991

Question: By international agreements, what is the most environmentally protected place on the Earth?

Answer: Antarctica

Question: What other natural product can clean electronic chips besides harmful CFCs?

Answer: Citric juice

Question: How many years does it take for the stratosphere to mix?

Answer: 3 - 5 years

Blue Level Questions:

correct answers = advance 3 spaces
incorrect answers = return 3 spaces

Question: During what season of the year and at what latitude of the world is the ozone layer naturally thin?

Answer: Spring and at high latitudes either N or S. (60-90 degrees)

Question: At the time they were invented, what were two advantages of CFCs?

Answer: Nontoxic and odorless

Question: Name 3 harmful side effects of ozone in either the troposphere or stratosphere (must get all 3 right).

Answer:
1) Skin cancer
2) Smog
3) Global climate change or warming

Question: Name 3 modern conveniences which use CFCs (must get all 3).

Answer:
1) Refrigerators or freezers
2) Air conditioners
3) Foam insulation

Question: Name the station in Antarctica where the ozone hole was first discovered.

Answer: Halley Bay

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Question: Name 3 ways ozone layer depletion is presently being monitored (must get all 3).

Answer: 1) Satellites
2) Airplanes
3) Balloons

Question: What controls the balance of ozone in the stratosphere?

Answer: The rate at which it is produced by by chemical processes, sunlight and the rate it is destroyed.

Question: Name 3 things which can destroy Ozone in the stratosphere.

Answer: 1) Chlorine or CFC
2) Cloud surfaces
3) Light

Question: Name 3 practical suggestions to reduce your chances of getting skin cancer when out in the sun?

Answer: 1) Wear protective clothing
2) Use sun screen
3) Minimize time in the sun between 10 am - 3 pm.

Question: In what layer of the atmosphere is increased ozone a problem?

Answer: Troposphere

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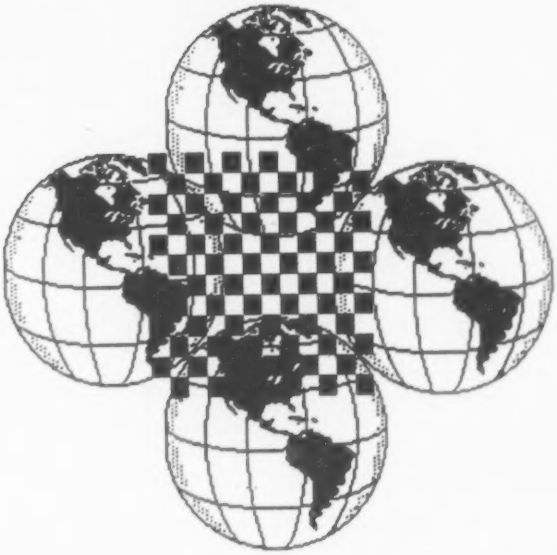
VIDEO:

WGBH Foundation. 1990. "Only One Atmosphere." *Race to Save the Planet.* This program concentrates on the various atmospheric problems such as ozone depletion, CO_2 enrichment, acid precipitation, etc. A 10 - 15 minute segment at the beginning of this program deals with the ozone hole and depletion. This segment could be used as an excellent introduction to the topic.

Annenberg/CPB Project, The WGBH Science Unit in Association with Chedd-Angier, Film Australia, The University Grants, Commission of India, Gujarat University/EMRC produced this series, *Race to Save the Planet,* and many other excellent productions. There are five programs in this production, examining different environmental topics.



THE GLOBAL CLIMATE GAME

This game is designed to help students explore the various aspects of global climate and to learn how human activity may affect climate. The game is to be played by students in groups of five. Each student will play an important role and will have a certain point of view. The group will be responsible for making decisions about activities that may impact global climate. These decisions should be based on information supplied to the group throughout or before the game.

[This game may appear to have an excessive number of pages, however, it is an excellent method of transmitting this climate information to the students and does not require an inordinate amount of time.]

Objectives: After completing this activity, each student will be to:

1) identify the various human impacts on the environment.
2) explain how lifestyles may be altered to become more favorable to the environment.
3) examine the role of individual decisions and their impact on the natural environment.

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3, 4, and 7. Refer to the Framework for ESE for a detailed description of each understanding.

Activity A: The Global Climate Game.

The day before the game is to be played, students should be assigned to groups of five. Students in each group should decide which role to play (Scientist, Industrialist, Citizen, Politician, or Environmental Activist). In preparation for the game, students should take home and read their role cards and a description of how the game is played.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

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[You may want to have six students in the groups, with two assigned as Scientists (the largest role) or you can give all the students the Scientist information to read through before playing the game.]

Materials: "The Global Climate Game Board"; role information sheets; appropriate game pieces — small pieces of rock or small replicas of trees; computer database that includes the consequences for each option.

Procedure:

1) The day the game is to be played, students who share the same roles should get together for five or ten minutes to discuss the roles they are playing and if needed, ask the teacher for direction. The students should then go back to their groups of five and play the game.

2) Set up the game board. Place the IMPACT cards face down on the area marked IMPACT on the board. Put the game piece on START. Because the actions of one individual or group of individuals can have an impact on us all, the group will have only one game piece to move.

3) The game should begin with each student reading his/her role card to the rest of the group. Begin with the student who is the Scientist and then the player to the left and so on. All students should have a set of information sheets that will be used to provide information when a student lands on an IMPACT space and selects an IMPACT card.

4) Play begins with the Citizen rolling the die and moving the game piece the number of spaces specified by the roll. Students may start on any space they wish. If the game piece lands on an IMPACT space, the student reads an IMPACT card to the group (see IMPACT card description below). If the game piece lands on one of the other spaces, the student should read what is on the space and the group should tally the appropriate number of environmental points.

5) Students should take turns rolling the die.

6) IMPACT Cards — When a game piece lands on an IMPACT space, the student picks up one IMPACT card and reads the situation presented on the card to the group. Each person in the group should respond to the situation based on the role that he or she is playing. Begin with the Scientist reading the information for the specific IMPACT card that was drawn. Each person in the group should describe how the situation is related to the role that he or she is playing.

7) Once the role play is finished, the students in each group must decide which of the possible actions it will take in response to the action. They do this by reading all of the possibilities on the appropriate OPTIONS card and coming to a group consensus.

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8) After the decision is made, look up the number of environmental points the group earned as a result of the decision. This information is available from the teacher or the computer database. Add this number to the other environmental points from other IMPACT cards and from the other spaces on the game board. Return the IMPACT card to the bottom of the pile and continue the game with the next player.

9) The game ends when the group has used all five IMPACT cards once or when the time limit set by the teacher is reached.

10) The goal of the game is to minimize the impact of human activity on global climate. This will be reflected in the number of environmental points that the groups accumulate. The final score is determined by converting the group's environmental points into the number of degrees of global warming using the Final Score scale.

Evaluation:

Based on the experience playing the game, each group is to prepare and present an environmental action plan to the teacher and the rest of the class. This plan must include at least one recommendation from each of the roles that were played in each group. The recommendations are suggestions of things that could be done to minimize the effects of human activity on global climate. The presentations can be as long as necessary but should be at least 5 minutes long. Be creative. Presentations can be skits, with each person playing his/her role; forums; oral reports; or any other method. Make and use visuals. Remember that the main or primary purpose of the presentations is to give a set of recommendations for action to minimize the influence of human activity on global climate.

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O. ZONE D. PLETION

Statement to read to the group at the beginning of the game:

> I am a scientist. I represent the work done by all scientists studying global climate change. Much of the information that I have gathered deals with natural and human records of climate and how it has changed through time. Using this information, instruments for collecting data in the atmosphere today, and global circulation models of the atmosphere and oceans, I am trying to predict how future climate during the game.

Use this information to play your role and make sure that you use as much of this information as possible. Use the sections of information indicated below for each Impact Card.

IMPACT CARD	SECTIONS TO USE
A	A, B, D, E, H
B	A, B, F, H
C	A, C
S	A, B, G, H
T	A, B, E, H

Section A — The Greenhouse Effect

Knowledge of what the greenhouse effect is will be assumed (see The Goldilocks Problem Activity). Carbon dioxide (CO_2), methane (CH_4), water vapor (H_2O), ozone (O_3) chlorofluorocarbons (CFCs) and nitrous oxide (N_2O) are the gases primarily involved in the greenhouse effect. The most important gas, CO_2, accounts for about one-half of human induced greenhouse warming. Be sure to discuss the sources and sinks of the gases involved and the possible feedbacks.

Section B — CO_2

Sources: Sources of CO_2 include volcanic activity, weathering of rocks, and by-products of respiration. Humans add approximately 6 million tons of carbon to the atmosphere every year, largely in the form of CO_2. The major human activities that release CO_2 include the burning of fossil fuels and wood to produce electricity, heat, and to operate vehicles like cars and trucks. It has been estimated that the amount of CO_2 in Earth's atmosphere will double in the next 40 to 50 years as a result of these human activities. Computer models estimate that this could increase Earth's overall average temperature 3 to 5°C. This may produce a variety of effects: Polar ice could melt and cause sea levels to rise, and worldwide climatic regions could shift and have major effects on farming especially in the American Midwest. CO_2 concentrations in the atmosphere are increasing about 0.3% per year. CO_2 accounts for about 50% of the human contribution to global warming.

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Sinks: Oceans dissolve large amounts of CO_2 from the atmosphere, including about one-half of the human-generated CO_2 added to the atmosphere every year. Many organisms use the CO_2 dissolved in water to build calcareous shells that become part of the sediment on the ocean floor when these organisms die. Photosynthetic plants in the oceans and on land use large amounts of CO_2.

Possible Feedbacks: *(When one part of a system changes and other parts of the same system change in response, the changes are known as feedbacks.)*

Increased amounts of CO_2 in the atmosphere cause some plants to be more productive, perform more photosynthesis, so they use more CO_2. Because the negative effects of increased CO_2 could be reduced, this is known as a negative feedback.

Increased CO_2 and the resultant increase in temperature could cause more evaporation which could cause Earth to become more cloudy. The increased amount of cloud cover could block more of the energy coming from the Sun. This could be a negative feedback, although the role of clouds in the greenhouse effect is poorly understood.

Section C — CFCs

Sources: Chlorofluorocarbons (CFCs) do not occur naturally. They are chemical compounds manufactured by humans for a variety of uses. The major sources of CFCs in the atmosphere in the United States are leaky air conditioners and other cooling systems like refrigerators and freezers in which the CFCs are used as refrigerants. CFCs are also released into the environment when air conditioners and refrigerators are being serviced. CFCs have also been used as propellants in aerosol cans, foamblowing agents, and cleaning solvents used in the manufacture of silicon chips for computers. CFCs account for about 14% of the human contribution to global warming.

Sinks: CFCs react with ozone in the atmosphere. This is the primary cause of ozone depletion in the atmosphere. CFCs will break down many more times the weight of ozone than their own weight. It takes several years for a CFC molecule to reach the ozone layer, then it will destroy ozone for several months before it disappears. If the use of CFCs was discontinued right now, its effects in the atmosphere would last 100 years.

Possible Feedbacks: Unknown.

Section D — Ozone

Sources: Ozone and other gases account for 13% of the human contribution to global warming. In the lower atmosphere, ozone is made from the burning of fossil fuels — especially from car exhaust fumes and in the resultant smog — and by lightning. In the upper atmosphere, it is made by the dissociation of oxygen molecules by sunlight. In the upper atmosphere, ozone is not a greenhouse gas. In the lower atmosphere it is one.

Sinks: Ozone is eventually catalyzed by free radicals in the atmosphere. In the upper atmosphere this is caused in part by chlorine from CFCs and results in ozone depletion.

Possible Feedbacks: Unknown.

Section E — Models

Computer models called general circulation models (GCM'S) are one of the tools scientists use to try to predict how climate will change in the future. These models try to represent processes in the atmosphere and in the oceans. Many of these processes are poorly understood. One criticism of the models is that they may not accurately represent the characteristics of the atmosphere and the ocean. As a result, the predictions made by these models may not be very accurate. Another problem is that there is very little data for many places on Earth, especially the oceans. With a relatively small amount of data, the accuracy of the model is also suspect.

On the other hand, historical records show that global temperature has increased about 0.5°C in the last 120 years. Many scientists believe that this warming trend will continue.

Section F — Biological Diversity

Biological diversity is the rich assemblage of various species of organisms that live within an ecosystem. Tropical rainforests have the most diverse collection of species of organisms in the world. Millions of different species may be living within a square mile of tropical rainforest. The genetic pool of these organisms is immense. The vast majority of it lies undiscovered. The potential of the genetic material is great. Many drugs used in treating disease, and new strains of plants to further hybridize food crops so they are more productive are just two ways in which this genetic potential could be put to use. Deforestation causes the collapse of these ecosystems, the extinction of many species of organisms and may effect the ecosystem in which humans are a part.

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Section G — Fossil Fuels and CO_2

When fossil fuels (coal, oil, natural gas) are burned, one of the by-products is CO_2. The use of fossil fuels has increased dramatically in the last 125 years. Measurements of CO_2 in the atmosphere over this time period reveal an increase in its concentration. Computer models estimate that the amount of global warming that has occurred in the last 125 years is about 0.5°C. Whether or nor this warming is due to increased CO_2 is unknown.

Section H — Global Warming from N_2O, CH_4, H_2O vapor

N_2O (Nitrous oxide)

Sources: Nitrous oxide (N_2O) comes from the oceans, the burning of fossil and biomass fuels, and from the production and use of fertilizers. It accounts for about 6% of the human contribution to global warming.

Sinks: The concentration of N_2O is in equilibrium between the atmosphere and the ocean. The amount of N_2O that remains in the atmosphere depends in part on the temperature of the ocean surface.

Possible Feedbacks: As global warming increases and the temperature of the ocean increases, more N_2O will become dissolved in the ocean. This would be a negative feedback.

CH_4 (Methane)

Sources: Methane forms when dead organic material decomposes in the absence of oxygen. The primary source of methane is wetlands. Humans have contributed CH_4 to the atmosphere through cultivating rice and other wetland crops. Methane concentration in the atmosphere is currently increasing at a rate of about 1% per year. Methane is more effective than CO_2 at trapping heat, but it is in much lower concentrations in the atmosphere so it not as important as a greenhouse gas. The concentration of CH_4 in the atmosphere is increasing at a rate of about 1% per year. It accounts for about 14% of the human contribution to global warming.

Sinks: Methane also is dissolved in the ocean. There is no known way in which it is recycled.

Possible Feedbacks: There is a large amount of CH_4 tied up in ice crystals in the permanently frozen ground in the sub-arctic regions of the world. Global climate warming could warm these regions enough to melt some of this frozen ground, releasing CH_4 and further enhancing global warming. Warming could also begin anaerobic decomposition of organic soils near the Poles and this would create more CH_4 that would be released into the atmosphere. These are positive feedbacks.

H_2O (Water) Vapor

Sources: Water vapor enters the atmosphere by way of evaporation from the surface, especially from oceans, and from transpiration by plants. The amount of water vapor in the air varies greatly and is very localized. Human activity has affected the amount of water vapor in the atmosphere by increasing evaporation from irrigated farmland, especially in dry climate areas. These effects are quite local, so the overall effect of human activity on global warming is uncertain.

Sinks: Formation of clouds in the atmosphere and dew and frost on land. Precipitation from clouds returns water to the surface.

Possible Feedbacks: As the atmosphere warms, the amount of evaporation could increase. The increased amount of water vapor in the atmosphere would further enhance the greenhouse effect. This is a positive feedback. Increased amounts of water vapor in the atmosphere could lead to increased cloudiness. The role of clouds in the green-house effect is poorly understood. More cloudy skies could block more radiation from the sun. This is a possible negative feedback.

IAM N. VOLVED

Statement to read to the group at the beginning of the game:

> I am an average citizen. I read the newspaper and news magazines. I also watch the news on television. Therefore, I am well informed about issues that are in the media. I am very concerned about the environment and the things that humans are doing to endanger it. I am also very confused about what we can do about improving the environment and preserving it. It seems that scientists and politicians are not able to tell me what I can do to help. I am not sure how these problems affect me directly.

Use this information to play your role:

You live in or near a city. You own your house, with a mortgage, have two cars, are married, and have two children. The taxes on your income and on the house, as well as other living expenses, severely limit the amount of money you have to spend on vacations and other forms of recreation. You try to put a little money aside for your children's college fund. Higher taxes would be a real burden and could affect your lifestyle.

The increased attention in the media on environmental problems really concerns you. You worry not only about it affecting the quality of your life and the lives of your children, but also on the possible economic impact of these problems. In order to reduce emissions of harmful gases from power plants into the atmosphere, cleaner coal may have to be used. This coal is more expensive. Your electric bill would likely increase. Your car's air conditioner and the one in your house both leak CFCs, especially when they are being serviced.

Deforestation is something that you hear a lot about. Deforestation affects you because it leads to global warming. When the trees are cut down and burned, more CO_2 is added to the atmosphere and less is removed by photosynthesis. The cutting of the forest also destroys the habitats of many plants and animals, and so many of these become extinct.

Mailings from environmental groups arrive at your house every week. It is hard to know the differences among the different groups. You want to do something to support one of these groups and the work it does, but since you don't know about any of them in detail, it is hard to know who to trust.

One option you have is to conserve energy as much as possible. This effort should take place wherever you are; in the car, at home, and at work. Recycle everything you possibly can. Using recycled materials to make new products usually requires less energy than using new materials. Recycling not only conserves natural materials, it also conserves energy.

LOTSA POWER

Statement to read to the group at the beginning of the game:

I am an industrialist. I am a part of a group of manufacturers and electricity suppliers. We manufacture a variety of products for use in daily life, including automobiles, paper, and other items used by humans.

We are responsible for supplying electricity to industry and to private citizens. To do this, we burn coal. The heat from this is used to make steam, which drives turbines that turn generators to make electricity. Government regulations require us to reduce the emissions from our power plants for environmental reasons. We have been accused of giving off gases that cause acid rain. We need to use equipment to remove most of these harmful gases from the smoke from our power plants.

The only way that we could reduce the amount of CO_2 being released from the power plants is to install very complex equipment or to switch to a different fuel, like natural gas, that generates less CO_2. Either option will greatly increase operating costs. The price of electricity will increase. If consumers of electricity would actively conserve energy, then less CO_2 and other "acid rain gases" would be released into the atmosphere. A consequence of this, however, could be people losing their jobs. Any major kind of change for environmental reasons in any of our industries could cause people to lose jobs. In many cases, however, most of these people could be re-trained to do other jobs.

We do not believe that global warming is happening anyway. The atmosphere and oceans are too complex for the models that scientists use to predict climate change.

Use this information to play your role:

You have already invested millions of dollars in anti-pollution devices as a result of government regulations. Switching to a different fuel, or installing equipment to reduce CO_2 emissions would greatly increase your operating costs and the cost of electricity to consumers. An implication of a change of fuel source would be a loss of jobs by coal miners. If consumers actively conserve electricity, there would be a decrease of emissions from the power plants, but there could also be people who would lose their jobs from the power plants or at coal mines.

Some industries in your group use raw materials that come from rainforests. The quality and appearance of the products made from these materials would decline, in your opinion, if you used raw materials from other sources.

Most climate models predict an increase of global temperature of 3° to 5°C, but the models use data locations that are far apart. Some parts of the ocean/atmosphere system are poorly understood.

PREE SERVE NATURE

Read this statement to the group at the beginning of the game:

> I am an environmental advocate. I belong to an environmental group that monitors environmental concerns on a global level. We solicit money from people in order to take action against pollution and polluters, as well as try to protect existing environments. We support strong environmental legislation. We want all forms of polluting to end. We want all people to conserve energy and other natural resources. The environment is more important than company profit. We will resist all attempts to destroy the environment.

Use this information to play your role:

Companies have been polluting the environment since the beginning of the Industrial Revolution about 125 years ago. People were largely unaware that damage was being done until the dramatic pollution of Lake Erie in the late 1960's really heightened the environmental awareness of people across the country. The dumping of toxic chemicals into an unsafe landfill called the Love Canal, near Niagara Falls in New York, and the effects of these chemicals on the residents of the area also increased the public demand for action.

The national Clean Air Act of 1970 set limits on the amounts of pollutants that can be emitted into the atmosphere by industry. With the prospect of global climate warming being discussed in the media and among scientists, the awareness of the environment has continued to increase in the United States and throughout the rest of the world since the mid-1980s.

You are very concerned about the extinctions of thousands of species of organisms that result from the deforestation of tropical rainforests. The genetic material contained in these organisms could prove to be very beneficial to humans in the future. The damage to the ecosystem could also be harmful to humans in ways that are not yet fully understood. Global warming is an example of one such possibility.

As a result, many environmental groups have formed to bring action against environmental problems. Some groups have purchased land covered with rain forest so that the forest can be preserved. Others have sponsored the planting of trees. Others have pressured industry to be more environmentally aware and to make more environmentally safe products. Others have taken a more militant stance and have interfered with the operations of industry or have blocked whaling ships to stop the slaughter of whales.

In your role, you should do what you can to preserve the environment as much as possible, while taking action to improve those parts of the environment that can be harmed by human activities.

THE HONORABLE PLEZE EVRYBUDDY

Read this statement to the group at the beginning of the game:

> I am a member of U.S. Congress. I am responsible for passing legislation to help protect the environment, while at the same time protecting the interests of citizens and industrialists. I am concerned that the environment is being harmed. I also know that in order for there to be a concentrated national effort to protect the environment, the economy must be strong. Consequently, the interests of industrialists and people who run businesses are important. The interests of citizens are also important because they are the people who elect me to office.

Use this information to play your role:

You have been elected to look after the interests of the people in your district. This includes those people who want the environment to be preserved at all costs and those people who may lose their jobs as a result of some environmental action, like curtailing the use of coal as an energy source. You also receive support from people who help you to get elected and who have their own interests they want protected. These interests could be pro or anti-environmental. The Congress has a limited amount of money to spend on all aspects of the government, not just the environment. The money that is available to spend on the environment is limited, unless people are willing to spend less on another aspect of the government, such as defense, or social programs like housing for the poor, or welfare, or other programs.

One possible solution to the use of fossil fuels as sources of energy is the use nuclear energy. There is a stigma attached to this, though, especially after the reactor accident at Chernobyl. Nuclear energy makes some people very nervous and many people do not want reactors in their "backyard". There also are problems with handling and storing nuclear wastes.

The developing nations are in debt. Many of these countries have exploding populations. In some places, the solution to these problems has been to move people out into the rainforests, cut down the trees, and generate products like wood and beef that can earn capital with which they can try to balance out their debt. In many parts of the world, deforestation can not be stopped unless there is a long term commitment to address the social and economic problems of the people in these countries.

You are caught in the middle. No matter what you do, there will be people upset about it. You must, however, eventually take a stand on each issue, keeping in mind the varied concerns of the people you represent.

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IMPACT CARD "A"

Situation:

A bill is introduced into the U. S. Senate that would require that electric cars be used by everyone in the United States by the year 2010. These cars must have a range of 250 miles before needing a recharge and be capable of going at least 65 miles per hour. Cars with gasoline or diesel engines burn fossil fuels and produce CO_2 and ozone.

Each person in the group should consider this situation in light of the role you are to play. Take two minutes to prepare a short argument for "your side" of the situation. Present the arguments to your group, starting with the "scientist", who will include some information about CO_2 and ozone. Then take turns for the other roles in the group.

When you are finished, decide as a group what you will do in response to the situation. You must do one of the five things listed on the "OPTIONS" list for this impact card. See your teacher or access the data base to get the "OPTIONS" list for this impact card.

Doing nothing is not an option. There must be group consensus on which option you will take. Once you have made your decision, see your teacher or access the data base for the possible outcomes of your decision.

IMPACT CARD "T"

Situation:

A logging company begins a project to cut down 10,000 acres of forest in your state in order to make paper. The unused parts of the trees and the underbrush will be burned, releasing CO_2 into the atmosphere. The CO_2 that the trees would have removed from the atmosphere through photosynthesis will not be removed from the atmosphere.

Each person in the group should consider this situation in light of the role you are to play. Take two minutes to prepare a short argument for "your side" of the situation. Present the arguments to your group, starting with the "scientist", who will include some information about CO_2. Then take turns for the other roles in the group.

When you are finished, decide as a group what you will do in response to the situation. You must do one of the five things listed on the "OPTIONS" list for this impact card. See your teacher or access the data base to get the "OPTIONS" list for this impact card.

Doing nothing is not an option. There must be group consensus on which option you will take. Once you have made your decision, see your teacher or access the data base for the possible outcomes of your decision.

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OPTIONS FOR IMPACT CARD "A":

A1. You join an environmental group that supports the bill and write letters to your state's Senators in support of it.

A2. You go out and buy a big, heavy car that is not fuel efficient while you can still get one. You feel you need the comfort, speed, and safety of a big car.

A3. You decide to conserve energy, not only in your car, but at home and at work as well. You talk to other people about the bill and convince them of the importance of it passing into law, and get them to write letters to your state's Senators in support of it.

A4. You feel that the bill, if passed into law, will infringe upon your rights as a citizen. The range of the new cars will be much too small for taking trips. Stopping to recharge the car will be too much of a hassle. You start a group of people who actively oppose the bill and write a series of articles in the local newspapers to try to convince others to do the same.

A5. You decide to get more information about the bill, so you read conflicting views of it in the newspaper and magazines, and attend a local forum where speakers having different view points present their arguments for or against the bill. Then you wait and see how your Senators vote on the bill.

OPTIONS FOR IMPACT CARD "T":

T1. You personally help to plant or financially support the planting of 5,000 trees in your state.

T2. You throw all paper into the trash as soon as you are done with it. You cannot believe that the amount of paper you throw away really makes a difference in the environment.

T3. You organize and run a community-wide recycling program.

T4. You believe that the cutting of the trees is necessary to provide important paper products for business, industry and for private consumers. You also believe that the loggers have a right to make a living.

T5. You recycle newspapers at home and buy products at the store that have a minimum amount of paper packaging. You encourage other people to do the same.

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IMPACT CARD "C"

Situation:

An automobile service company owns several auto repair shops in your area. The company specializes in routine auto maintenance and quick service. CFCs are used in auto air conditioners as a refrigerant. When these auto repair shops recharge an air conditioner, they first empty the CFCs that are left in it and allow them to escape into the atmosphere. Then they refill it with "new" CFCs. They could trap the escaping CFC's and recycle them, but the equipment needed to do this is expensive.

Each person in the group should consider this situation in light of the role you are to play. Take two minutes to prepare a short argument for "your side" of the situation. Present the arguments to your group, starting with the "scientist", who will include some information about CFCs. Then take turns for the other roles in the group.

When you are finished, decide as a group what you will do in response to the situation. You must do one of the five things listed on the "OPTIONS" list for this impact card. See your teacher or access the data base to get the "OPTIONS" list for this impact card.

Doing nothing is not an option. There must be group consensus on which option you will take. Once you have made your decision, see your teacher or access the data base for the possible outcomes of your decision.

IMPACT CARD "B"

Situation:

Rainforests are being destroyed in many parts of the world, especially in the tropics. The reasons for this are varied. In some countries, the trees are being destroyed because of rapid population growth and the people need space and a way to survive. In other parts of the world, the trees are cut to be used for lumber or for burning as a source of energy. In many instances, the people involved have little choice about cutting the trees because it is the only way they can survive.

This has drastic effects on the environment. Exposed soils are eroded, leaving the land unsuitable for agriculture. If the wood is burned, CO_2 is released into the atmosphere. The loss of photosynthesis from the cut trees reduces the amount of CO_2 absorbed from the atmosphere and adds to global warming. Several species of plants and animals become extinct with a resultant loss of biodiversity because their habitats have been destroyed.

Each person in the group should consider this situation in light of the role you are to play. Take two minutes to prepare a short argument for "your side" of the situation. Present the arguments to your group, starting with the "scientist", who will include some information about CO_2 and biodiversity. Then take turns for the other roles in the group.

When you are finished, decide as a group what you will do in response to the situation. You must do one of the five things listed on the "OPTIONS" list for this impact card. See your teacher or access the data base to get the "OPTIONS" list for this impact card.

Doing nothing is not an option. There must be group consensus on which option you will take. Once you have made your decision, see your teacher or access the data base for the possible outcomes of your decision.

OPTIONS FOR IMPACT CARD "C":

C1. You boycott the auto repair shops until they get the equipment needed to recycle CFCs.

C2. You write letters to the owners of the auto repair shops encouraging them to purchase the equipment to recycle CFCs. You get other people to do the same.

C3. You get your car's air conditioner serviced at one of the repair shops because you feel that the little bit of CFCs from your car could not possibly make that much of a difference to the environment.

C4. You do not get your car's air conditioner serviced, even though it needs to be recharged. The next time you buy a car, you get one without an air conditioner in it.

C5. You write letters and encourage other people to write letters to auto manufacturers and encourage them to use air conditioners that have refrigerants that do not affect the environment. In addition, you put pressure on politicians to pass legislation outlawing the use of CFCs for any purpose.

OPTIONS FOR IMPACT CARD "B":

B1. You decide not to buy things from companies that use materials they obtained as a result of deforestation. You find out about these companies by asking for information from reputable environmental organizations.

B2. The tropics are far away from where you live. You feel that deforestation has little to do with your every day life. You make little effort to find out what you can do about deforestation. You continue to buy products that result in deforestation, although there are similar products that you could use that do not promote deforestation.

B3. You join and financially support organizations that purchase and preserve large tracts of land that are covered by tropical rainforest. In addition, these organizations work with the governments of the countries where deforestation is occurring to develop ways to help those people who have been cutting the trees survive without destroying the rainforest.

B4. You feel that the people in the countries where deforestation is occurring have a right to be left alone. You also enjoy and are a big consumer of products made as a result of deforestation. These might include beef from cattle ranches or products made from tropical woods.

B5. You and others lobby Congress for the United States to offer financial assistance and economic advice to countries where deforestation is occurring. In addition, you get everyone you know to reduce their use of products that come from deforestation.

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IMPACT CARD "S"

Situation:

The city government decides to offer home energy audits free of charge to all homeowners in the city. A home energy audit is when a person or persons visit your home and use equipment to measure the amount of energy use and loss in various parts of it. This can also be done in part remotely using aerial infrared photography in the wintertime to spot heat loss from your house.

The city introduces legislation to establish a carpool lane for rush hour traffic on the freeways. Only cars with at least three people in them are allowed to travel in the carpool lane. These cars are also allowed to go 10 MPH faster than cars with only one person in them.

Each person in the group should consider this situation in light of the role you are to play. Take two minutes to prepare a short argument for "your side" of the situation. Present the arguments to your group, starting with the "scientist", who will include some information about energy and CO_2. Then take turns for the other roles in the group.

When you are finished, decide as a group what you will do in response to the situation. You must do one of the five things listed on the "OPTIONS" list for this impact card. See your teacher or access the data base to get the "OPTIONS" list for this impact card.

Doing nothing is not an option. There must be group consensus on which option you will take. Once you have made your decision, see your teacher or access the data base for the possible outcomes of your decision.

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OPTIONS FOR IMPACT CARD "S":

S1.
- a. You have a home energy audit done for your home.
- b. You have the house insulated and plant deciduous trees in the yard to shade the house in summer.
- c. a. and b. cost $2,500.
- d. You do not carpool, but you begin to ride the bus to work twice a week.
- e. You replace worn out appliances with the cheapest ones possible.

S2.
- a. You do not have an energy audit done for your house.
- b. You do not carpool.
- c. You do not use mass transit to get to work.
- d. When appliances wear out, you buy the cheapest replacements possible.

S3.
- a. You have an energy audit done for your house.
- b. You insulate your house and plant deciduous trees in the yard to shade the house in summer.
- c. a. and b. cost $2,500.
- d. You find two other people to carpool with you to work.

S4.
- a. You have a home energy audit done for your house.
- b. You do not have the house insulated (too expensive, would cost $2,000.)
- c. You find three people with whom you can carpool to work.
- d. When the refrigerator breaks down, you replace it with one that is very energy efficient.

S5.
- a. You have a home energy audit done for your house.
- b. You insulate the house and plant deciduous trees in the yard to shade the house in summer.
- c. a. and b. cost $2,500.
- d. You find two people with whom to carpool.
- e. Your furnace and air conditioner break down and you replace them with models that are 50% more energy efficient the old ones.
- f. The more efficient furnace and air conditioner cost an extra $1,000 compared to less efficient ones.

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Consequences can be entered into a computer database so that by typing in the chosen option, the consequences appear.

IMPACT CARD "A" POSSIBLE CONSEQUENCES

A1. As a result of your support, the bill passes. Over the next 20 years, automobile manufacturers invest millions of dollars in developing the new cars and the batteries needed to store the energy to run the cars. The auto manufacturers can not do this on their own, however, so they ask for government support. As a result, taxes increase. This leaves you with less spending money, but you don't care because you have helped to preserve the environment.

You have not reduced the amount of CO_2 as much as you think. The electricity needed to recharge the batteries of the new cars comes in large part from power plants that burn fossil fuels. You have decreased the emissions of cars, but increased the emissions of power plants. Power plants are generally more efficient than cars, however, and the use of the very efficient new batteries do lead to a net reduction in the amount of CO_2 being put into the atmosphere by human activity.

Score: + 20 Environmental Points.

A2. You are not alone in your feelings about big gas-guzzling cars. Sales of big cars increase dramatically, prompting U.S. auto manufacturers to build as many large cars as possible before they might have to sell only electric cars. The increased use of these larger inefficient cars leads to a dramatic increase in the amount of CO_2 and ozone in the atmosphere. The amount of smog in large cities also increases. More people in these cities get respiratory illnesses. Supplies of gasoline are diminished because of greater use. The cost of living rises because of higher fuel and health care costs. Increased amounts of CO_2 and ozone enhance the greenhouse effect.

Score: - 40 Environmental Points.

A3. As a result of your support, the bill passes. Over the next 20 years, automobile manufacturers invest millions of dollars in developing the new cars and the batteries needed to store the energy to run the cars. The auto manufacturers can not do this on their own, however, so they ask for government support. In addition, the Senators are so overwhelmed by the support for this bill that they pass other legislation that guarantees that the electricity for recharging the batteries can only come from power sources that do not use fossil fuels. This legislation also provides for developing more efficient mass transportation to allow people to travel long distances. All of this will cost millions and millions of dollars. This leaves you with less money for your family, but you don't mind because you have helped to preserve the environment for your children and for future generations.

Score: + 60 Environmental Points.

A4. As a result of your actions, the bill does not pass. This is interpreted by members of Congress, Senators, and auto manufacturers as a message that says that things are all right as they are. Nothing is done about the emissions of CO_2 and ozone from cars. The amount of CO_2 and ozone in the atmosphere continues to increase at the present rate, adding to global warming.

Score: - 20 Environmental Points.

A5. Even though you are concerned, you have not actively participated in the process of this bill becoming a law. Other people have made your decision for you. You have also not done anything personally to help reduce the amount of human activity-related CO_2 and ozone that is being put into the atmosphere. The amount of CO_2 and ozone in the atmosphere continues to increase at the present rate, adding to global warming.

Score: - 20 Environmental Points.

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IMPACT CARD "T" POSSIBLE CONSEQUENCES

T1. The trees that you plant help to offset the environmental damage done by the logging. They partially compensate for the lost CO_2 — absorbing potential of the logged trees, but there is still a net increase of CO_2 in the atmosphere. The logging also destroyed the habitat of many animals and plants other than trees. Some of these organisms are endangered and may become extinct.

The planting of the trees was expensive, either financially, or in the time it took you to plant the trees yourself. As far as global warming is concerned, however, planting the trees was a good effort.

Score: + 20 Environmental Points.

T2. By throwing away all paper materials when you are done with them, you encourage the logging of forests. Instead of paper being recycled, trees must be cut down to create paper products. Not only does this contribute to global warming, but it also destroys the habitats of a variety of organisms, some of which are endangered and may become extinct. The burning of unusable parts of trees and of underbrush adds CO_2 to the atmosphere. Fewer trees means less photosynthesis, and so less CO_2 is removed from the atmosphere. The net result is that the amount of CO_2 in the atmosphere is increased

Score: - 50 Environmental Points.

T3. The recycling of paper by the entire community decreases the demand for using new wood from trees to make paper products. The amount of logging decreases. More forests are preserved, along with the ability of the trees to absorb CO_2. Other resources are recycled at your center also, leading to their conservation as well as the conservation of energy needed to process them. Energy conservation means less burning of fossil fuels and consequently less CO_2 entering the atmosphere. Your actions have decreased the amount of CO_2 , so the effect of human activity on global warming is reduced.

Score: + 40 Environmental Points.

T4. Your concern for the jobs of the loggers is good. There are always tradeoffs in this kind of situation. Your inaction in this situation encourages the logging of forests. Instead of paper being recycled, trees must be cut down to create paper products. Not only does this contribute to global warming, but it also destroys the habitats of a variety of organisms, some of which are endangered and may become extinct. The burning of unusable parts of trees and of underbrush adds CO_2 to the atmosphere. Fewer trees means less photosynthesis, and so less CO_2 is removed from the atmosphere. The net result is that the amount of CO_2 in the atmosphere is increased and global warming is accelerated.

Score: - 50 Environmental Points.

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T5. Your actions and your willingness to get other people involved reduce the demand for the logging of trees to make paper products. The amount of logging decreases. More forests are preserved, along with the ability of the trees to absorb CO_2. Other resources are recycled at your center also, leading to their conservation as well as the conservation of the energy needed to process them. Energy conservation means less burning of fossil fuels and consequently less CO_2 entering the atmosphere. Your actions have decreased the amount of CO_2 entering the atmosphere, so the effect of human activity on global warming is reduced.

Score: + 40 Environmental Points.

IMPACT CARD "C" POSSIBLE CONSEQUENCES

C1. If you are able to convince enough other people to boycott the auto repair shops, they could go out of business. If you have taken your business to other auto repair shops that do capture and recycle CFCs, then you have prevented some CFCs from entering the atmosphere. In the lower atmosphere, CFCs are effective at trapping heat. In the upper atmosphere, CFCs are effective at destroying ozone which helps to protect living organisms, including ourselves, from the harmful effects of ultraviolet radiation from the Sun. Your actions have helped to reduce the amount of warming in the lower atmosphere and also the amount of ozone depletion in the upper atmosphere. If the auto repair shops do go out of business, some people will lose their jobs, but they are able to find jobs elsewhere.

Score: + 20 Environmental Points.

C2. Your letter writing results in the owners of the auto repair shops purchasing the equipment needed to capture and recycle CFCs. You have prevented some CFCs from entering the atmosphere. In the lower atmosphere, CFCs are effective at trapping heat. In the upper atmosphere, CFCs are effective at destroying ozone which helps to protect living organisms, including ourselves, from the harmful effects of ultraviolet radiation from the Sun. Your actions have helped to reduce the amount of warming in the lower atmosphere and also the amount of ozone depletion in the upper atmosphere. The cost of the new equipment causes prices at the auto repair shop to increase. You pay a little more than you did before, but it is worth it to help protect the environment.

Score: + 20 Environmental Points.

C3. Many other people, like yourself, are not concerned with CFCs being released into the environment. By your inaction, CFCs are added to the atmosphere at a greater rate, increasing global warming. The CFCs also attack ozone in the upper atmosphere. More harmful ultraviolet radiation reaches the surface of Earth. There is an increase in skin cancer among people in the United States. Certain crops do not grow as well in the increased radiation. The cost of living increases, including health care costs.

Score: - 40 Environmental Points.

C4. You have allowed some CFCs to escape into the atmosphere in the past by not getting your car's air conditioner serviced when it was needed. By not having the air conditioner recharged, however, you are preventing future leaks of CFCs from your own car. In the lower atmosphere, CFCs are effective at trapping heat. In the upper atmosphere, CFCs are effective at destroying ozone which helps to protect living organisms, including ourselves, from the harmful effects of ultraviolet radiation from the Sun. Your actions have helped to reduce the amount of warming in the lower atmosphere and also the amount of ozone depletion in the upper atmosphere.

Score: + 10 Environmental Points.

C5. As a result of the letter writing campaign that you started, auto manufacturers begin to use auto air conditioners that have refrigerants that are not harmful to the environment. The U.S. Congress passes special environmental legislation requiring all industries that use CFCs to phase them out over the next five years and use gases that are not harmful to the environment. Your actions have decreased the amount of CFCs that will be put into the atmosphere in the future. In the lower atmosphere, CFCs are effective at trapping heat. In the upper atmosphere, CFCs are effective at destroying ozone which helps to protect living organisms, including ourselves, from the harmful effects of ultraviolet radiation from the Sun. Your actions have helped to reduce the amount of warming in the lower atmosphere and also the amount of ozone depletion in the upper atmosphere.

Score: + 50 Environmental Points.

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IMPACT CARD "B" POSSIBLE CONSEQUENCES

B1. As a result of your actions, companies who profit from deforestation lose some business. They begin the realize that in order to remain competitive in the marketplace, they need to respond to your wishes. They begin to look for other sources of raw materials that do not promote deforestation. These other sources may be more expensive, so the price of the products might increase.

The rainforest in some areas may be a little more protected than before. There is less CO_2 put into the atmosphere because of the decomposition or burning of the wood, and less photosynthetic activity is lost so more CO_2 is removed from the atmosphere. This reduces global warming.

By helping to reduce deforestation, the biological diversity of the rainforest is preserved. The genetic stock of these organisms, some of which will undoubtedly be useful to humans, is therefore preserved.

Score: + 20 Environmental Points.

B2. You have done nothing to prevent the deforestation of rainforests. You have not altered your use of products that depend upon deforestation. Efforts to help the governments of countries solve the problems of deforestation do not happen because of a lack of support. Rainforests continue to be destroyed. Several species of plants and animals become extinct. The genetic stock of these organisms, some of which would undoubtedly be useful to humans, is lost.

Score: - 20 Environmentai Points.

B3. You have been able to slow the rate of deforestation. The use of products that rely upon deforestation has been reduced. The companies that manufacture these products have begun to find and use sources of raw materials that do not depend upon deforestation. The governments of countries where deforestation is occurring are helping those people who have been cutting down the forests to find alternative ways to survive. Part of this help is the result of financial aid from the United States in the form of money or as debt reduction.

Slowed deforestation reduces the amount of CO_2 that is being added to the atmosphere. Photosynthesis in the preserved rainforest continues to remove CO_2 from the atmosphere. Both of these help to reduce global warming.

Slowed deforestation also helps to preserve the biological diversity of the tropics. The genetic stock of organisms in the rainforest, some of which will undoubtedly be useful to humans, is preserved.

Score: + 40 Environmental Points.

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B4. You have done nothing to prevent the deforestation of rainforests. In fact, you have encouraged it. You have increased your use of products that depend upon deforestation. Efforts to help the governments of countries solve the problems of deforestation do not happen because of a lack of support. Rainforests continue to be destroyed. Several species of plants and animals become extinct. The genetic stock of these organisms, some of which would undoubtedly be useful to humans, is lost.

Score: - 40 Environmental Points.

B5. You have been able to slow the rate of deforestation. The use of products that rely upon deforestation has been reduced. The companies that manufacture these products have begun to find and use sources of raw materials that do not depend upon deforestation. The governments of countries where deforestation is occurring are helping those people who have been cutting down the forests to find alternative ways to survive. Part of this help is the result of financial aid from the United States in the form of money or as debt reduction.

Slowed deforestation reduces the amount of CO_2 that is being added to the atmosphere. Photosynthesis in the preserved rainforest continues to remove CO_2 from the atmosphere. Both of these help to reduce global warming.

Slowed deforestation also helps to preserve the biological diversity of the tropics. The genetic stock of organisms in the rainforest, some of which will undoubtedly be useful to humans, is preserved.

Score: + 40 Environmental Points.

IMPACT CARD "S" POSSIBLE CONSEQUENCES

S1. By having your house insulated and planting trees in the yard, you have more heat in the winter and there is less heat in the summer because of the shade from the trees. Your house uses energy more efficiently, so lesser amounts of fossil fuels are burned, and less CO_2 is put into the atmosphere. You will save $250 per year in energy costs, so in about 10 years you will get your investment back and then will actually save a considerable amount of money, especially if the cost of energy increases.

Riding the bus to work twice a week also reduces the use of fossil fuels, but not as much as you would if you carpool with two or three other people or if you ride the bus every day. Carpooling or riding the bus saves wear and tear on your car, so it lasts longer and the energy costs for producing a new one are also saved.

When appliances wear out, you buy replacements that are cheap, but not necessarily energy efficient. You could save considerable amounts of energy by using energy efficient appliances and at the same time decrease your effect on the environment, especially global warming.

Score: + 30 Environmental Points.

S2. By not doing anything to stop the loss of energy from your house and the inefficient use of energy in your car, a large amount of CO_2 is released into the atmosphere. This adds to global warming. The amount of energy that is wasted costs you an extra $350 per year that could have been saved by acting on the recommendations of an energy audit.

Score: - 50 Environmental Points.

S3. By having your house insulated and planting trees in the yard, you have reduced your use of energy year round. Less heat leaks out of the house in the winter and there is less heat in the summer because of the shade from the trees. Your house uses energy more efficiently, so lesser amounts of fossil fuels are burned, and less CO_2 is put into the atmosphere. You will save $250 per year in energy costs, so in about 10 years you will get your investment back and then will actually save a considerable amount of money, especially if the cost of energy increases.
There are other things that you could do to save energy around the house. You could use energy efficient light bulbs, energy efficient appliances and an energy efficient furnace and air conditioner. This could save substantial amounts of energy and reduce the amount of CO_2 released into the atmosphere.

Carpooling with two other people will save a substantial amount of gasoline. Less CO_2 will be put into the atmosphere, so global warming will be reduced. There will also be less wear and tear on your car, so you will not have to replace it as quickly, thereby saving the energy needed to build a new car.

Score: + 40 Environmental Points.

S4. By not having your house insulated, you continue to allow a tremendous amount of energy to be wasted. The amount of energy that is wasted costs you an extra $250 dollars per year and adds thousands of pounds of CO_2 to the atmosphere from the power plant. Something as simple as planting trees in the yard to shade the house in the summertime would reduce the energy requirements you need to cool the house.

Carpooling with three other people reduces the use of fossil fuels and the release of CO_2 into the atmosphere. There is also less wear and tear on your car. Your car lasts longer, so the energy needed to make a new car for you is saved and less CO_2 has been put into the atmosphere.

Replacing your refrigerator with one that is very energy efficient saves a considerable amount of energy. The saving of energy also means a saving of money for you. The greater cost of the more energy efficient refrigerator is paid off in money from energy savings in 5 years. Less CO_2 has also been put in the atmosphere.

Score: + 10 Environmental Points.

S5. By having your house insulated and planting trees in the yard, you have reduced your use of energy year round. Less heat leaks out of the house in the winter and there is less heat in the summer because of the shade from the trees. Your house uses energy more efficiently, so lesser amounts of fossil fuels are burned, and less CO_2 is put into the atmosphere. You will save $250 per year in energy costs, so in about 10 years you will get your investment back and then will actually save a considerable amount of money, especially if the cost of energy increases.

Carpooling with two other people will save a substantial amount of gasoline. Less CO_2 will be put into the atmosphere, so global warming will be reduced. There will also be less wear and tear on your car, so you will not have to replace it as quickly, thereby saving the energy needed to build a new car.

Replacing your old broken-down furnace and air conditioner with new ones that are energy efficient will save you an extra $350 per year in energy costs. The extra cost of these machines in your home will be paid back to you in energy savings in about 3 to 4 years. There will also be substantially less CO_2 added to the atmosphere, reducing the effect you have on global warming.

Score: + 60 Environmental Points.

FINAL SCORE SCALE

Total number of Environmental Points	Possible Temperature Change in °C.
+200	+1.0
+150	+1.5
+100	+2.0
+ 50	+2.5
0	+3.0
- 50	+3.5
-100	+4.0
-150	+4.5
-200	+5.0
-250	+5.5

Note: This scale is only used for this simulation or game. It is to be used only to give you an idea of what might occur in the environment as a result of your actions.

Examining some of the temperature increases, predictions have been made for the following possible changes/events to occur.
+1°C — Average global sea level rise of 1 ft.; increased tropical storms; drought conditions in some countries, particularly in Africa; increase in global refugees.
+1.5°C — Average global sea level rise of 1ft. 2 inches; a high latitude warm-up; continuing drought; extensive crop failure; climatic extremes; starvation could cause in excess of 2 million deaths worldwide.
+3°C — Average global sea level rise of 2 ft.; severe vegetation loss; increasing water shortages. This rise in sea level would flood 12 -15% of Egypt's arable land and 17% of the total land area of Bangladesh. Major river deltas in China, Vietnam, Myanmar (Burma), Pakistan, Nigeria, Brazil, Italy, Argentina and the US would be threatened. Island nations would be severely affected. The Maldives would suffer the most economic losses, experiencing a reduction of 34% in their annual Gross Domestic Product (GDP). Ten other island nations and territories, including the

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Falklands, Seychelles and Marshalls would experience an annual loss of 5% or more in their GDP.

If by 2050 the increased temperature range is between 3 - 5°C, then large amounts of coastal areas will have disappeared as a consequence of sea level rise. It is estimated that 200 million Chinese will have to be evacuated; in Bangladesh 50 million people will be affected by the rising sea levels and a fifth of the country will be underwater. In Egypt, half of its industry will be inundated with saline water and all of south Florida would be submerged. By this time, a reduction of 20 million in the world's population will have resulted from floods, extreme storms and starvation.

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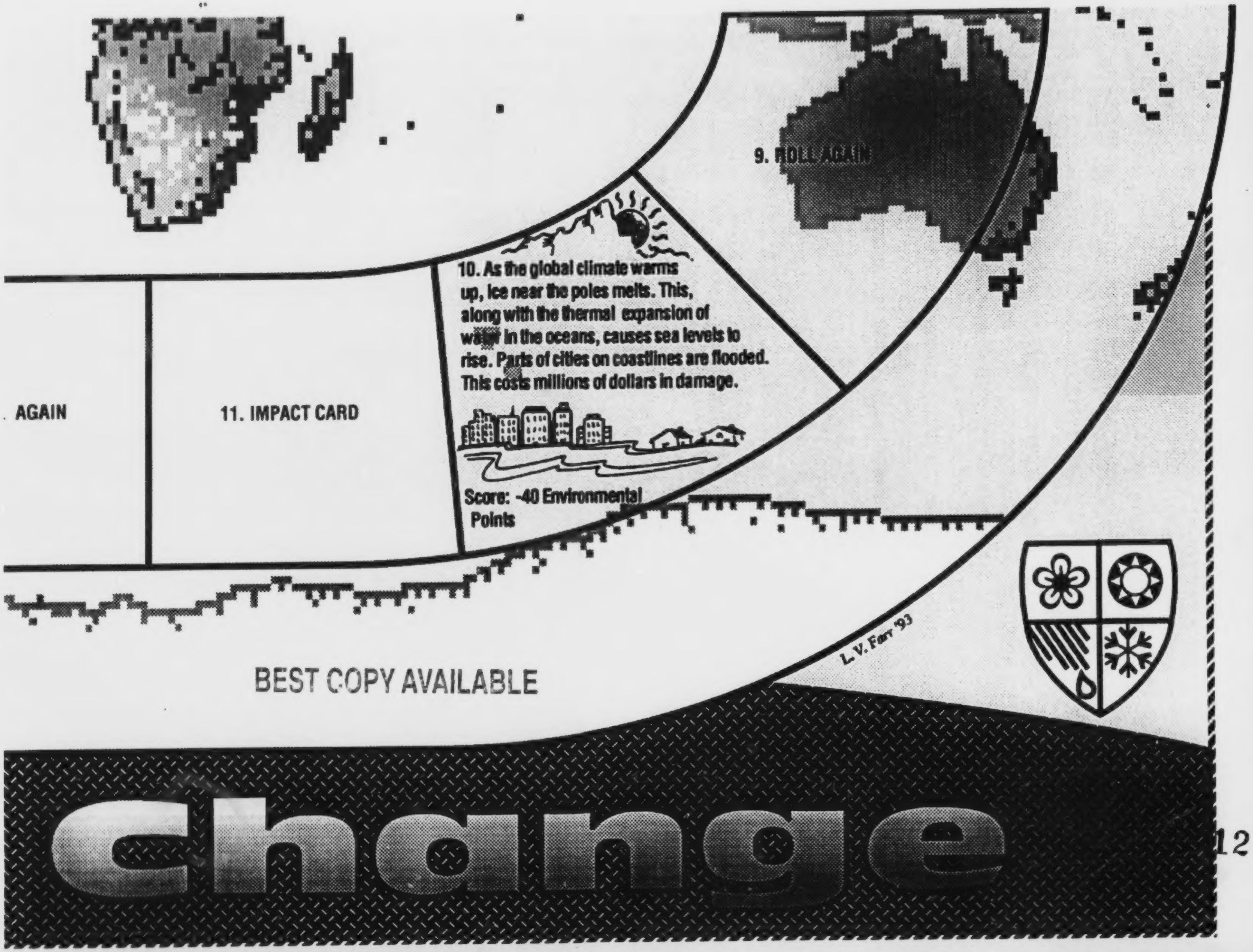
9. ROLL AGAIN
AGAIN
11. IMPACT CARD
L. V. Farr '93
Change

10. As the global climate warms up, ice near the poles melts. This, along with the thermal expansion of water in the oceans, causes sea levels to rise. Parts of cities on coastlines are flooded. This costs millions of dollars in damage.

Score: -40 Environmental Points

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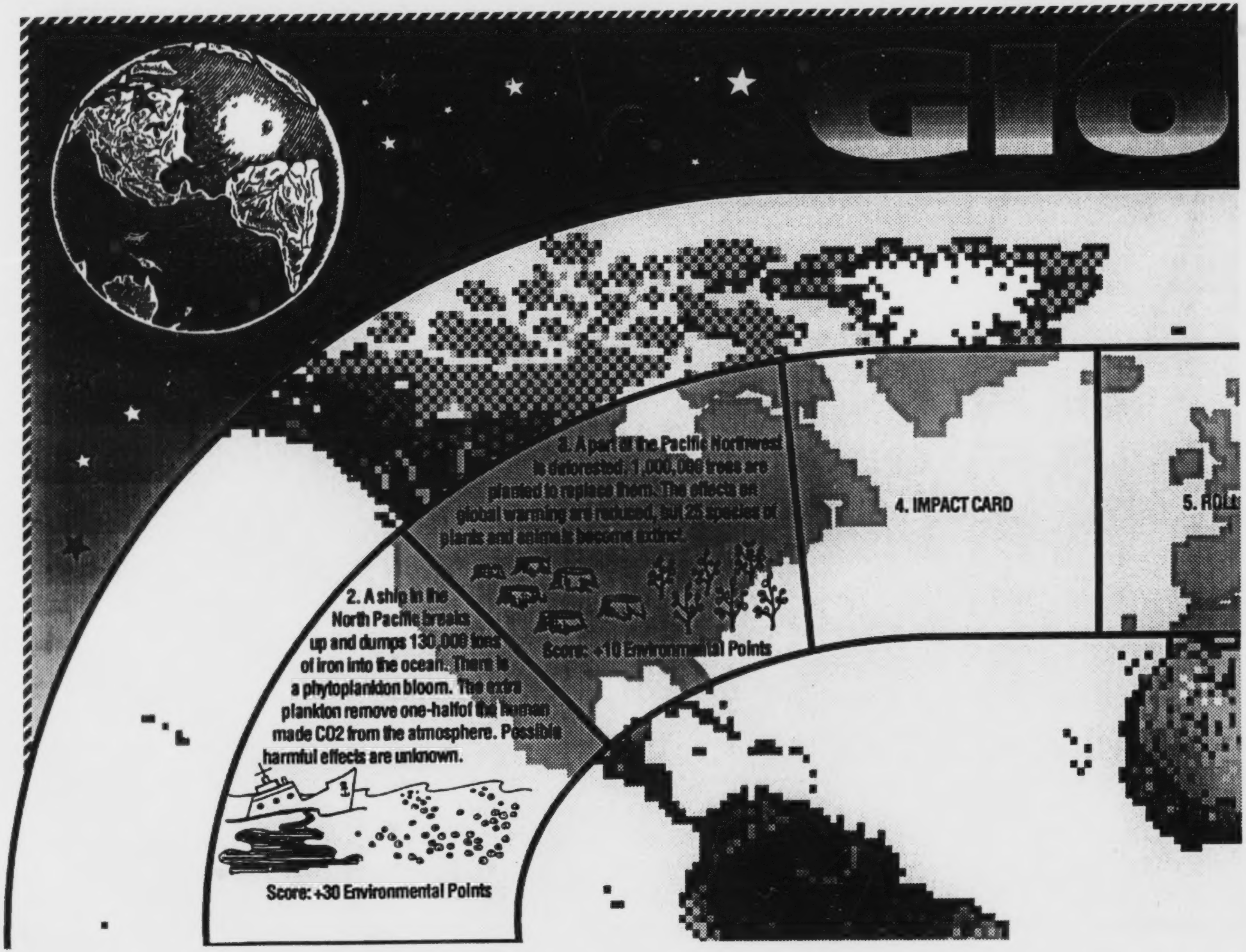

2. A ship in the North Pacific breaks up and dumps 130,000 tons of iron into the ocean. There is a phytoplankton bloom. The extra plankton remove one-half of the human made CO2 from the atmosphere. Possible harmful effects are unknown.

Score: +30 Environmental Points

3. A part of the Pacific Northwest is deforested. 1,000,000 trees are planted to replace them. The effects on global warming are reduced, but 25 species of plants and animals become extinct!

Score: +10 Environmental Points

4. IMPACT CARD

5. ROL

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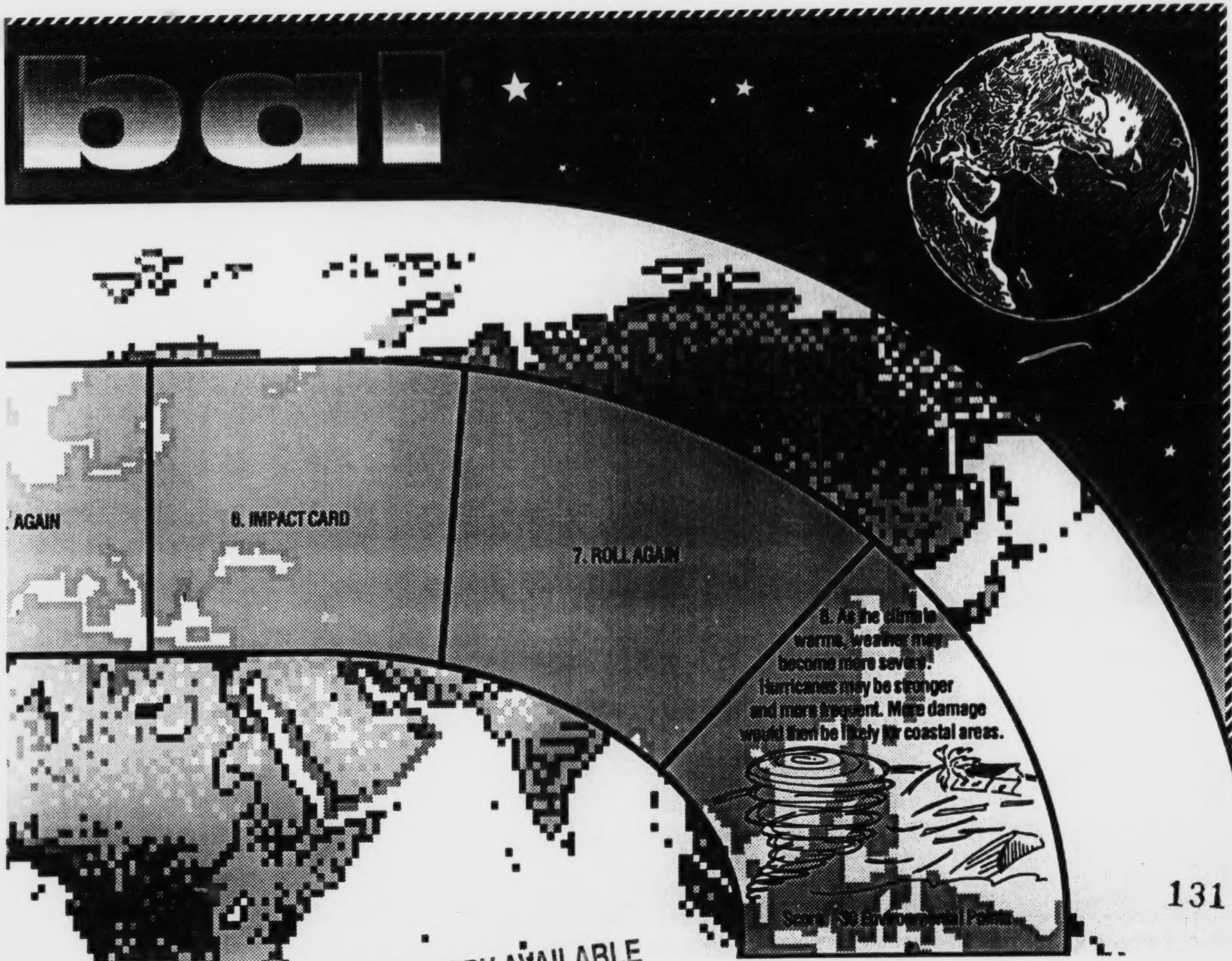
bal
AGAIN
6. IMPACT CARD
7. ROLL AGAIN

8. As the climate warms, weather may become more severe. Hurricanes may be stronger and more frequent. More damage would then be likely for coastal areas.

Score [illegible] Environmental Points

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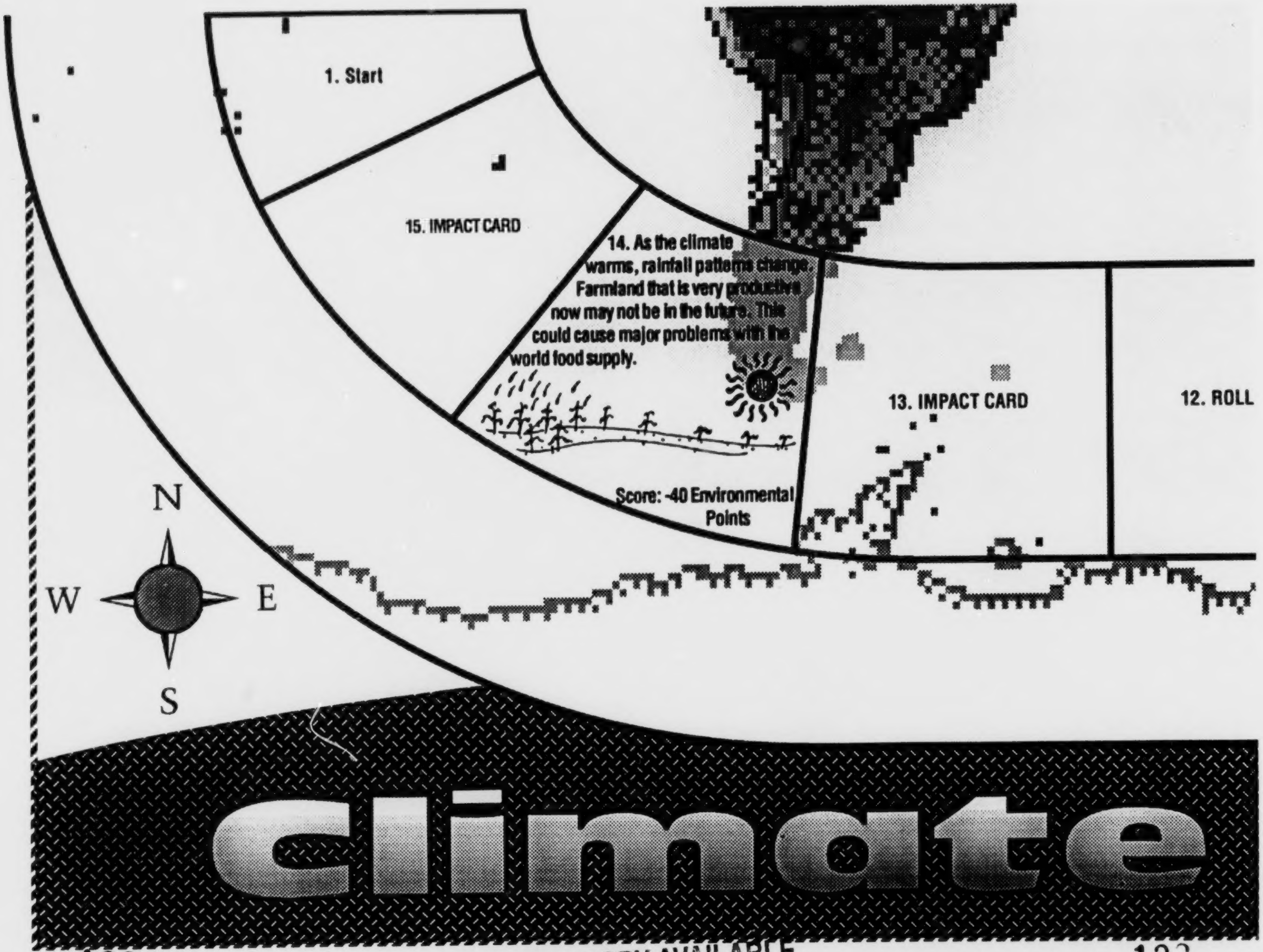
1. Start
15. IMPACT CARD
13. IMPACT CARD
12. ROLL
N
W
E
S
climate

14. As the climate warms, rainfall patterns change. Farmland that is very productive now may not be in the future. This could cause major problems with the world food supply.

Score: -40 Environmental Points

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HIGH SCHOOL
ACTIVITIES

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ICE CORES:

A KEY TO UNLOCKING EARTH'S CLIMATIC PAST

Every day, while we go about our normal activities, information about our climate is being recorded. Records are made not only by scientists, but also by Earth itself. Earth has kept records of climatic activity for thousands of years, but scientists have just recently begun to learn how these records can be "played back." There are many different Earth system "recorders," but this activity will describe only a few of them. Once we learn how the "system of climatic recording" operates, we will try to play back a few of Earth's climatic records.

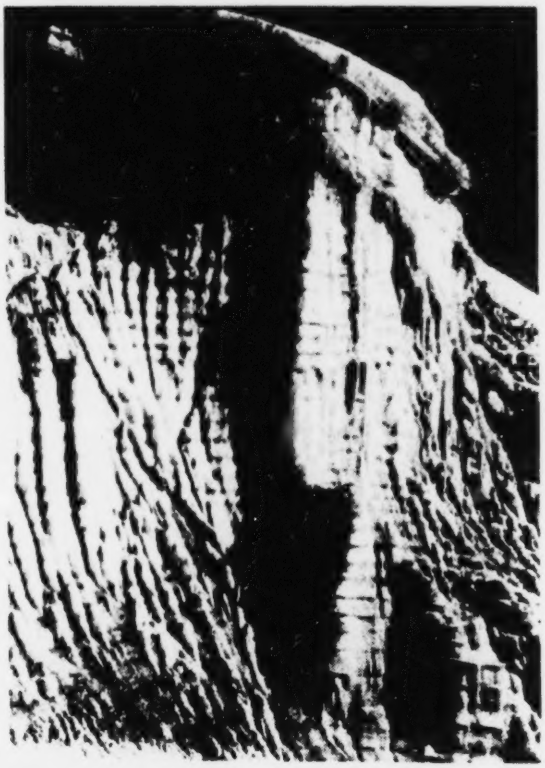

Figure 1. - Quelccaya Ice cap, Peru. Note the layers of ice, each representing one year's snowfall. (Source: Dr. L. G. Thompson, Byrd Polar Research Center, The Ohio State University.)

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

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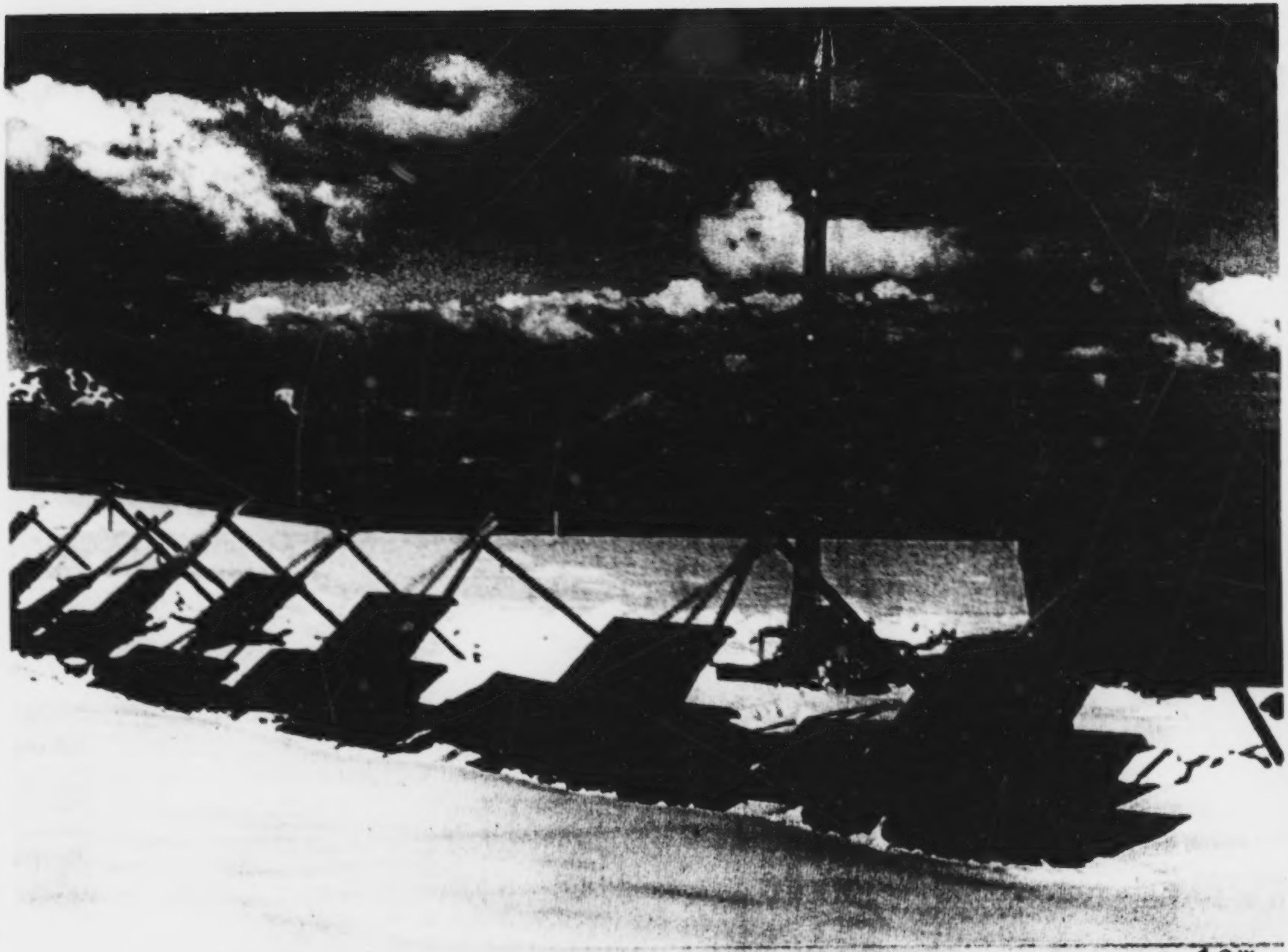

Figure 2. - This photograph illustrates the equipment necessary to obtain ice cores from glaciers or ice fields. (Source: Dr. L. G. Thompson, Byrd Polar Research Center, The Ohio State University.)

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SOLAR POWERED DRILL USED TO RECOVER TWO ICE CORES. ONE TO BEDROCK

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Figure 3. - Photograph of the Quelccaya Ice Field in 1979. (Source: Dr. L. G. Thompson, Byrd Polar Research Center, The Ohio State University.)

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Figure 4. - Photograph of the Quelccaya Ice Field taken in 1991. (Source: Dr. L. G. Thompson, Byrd Polar Research Center, The Ohio State University.)

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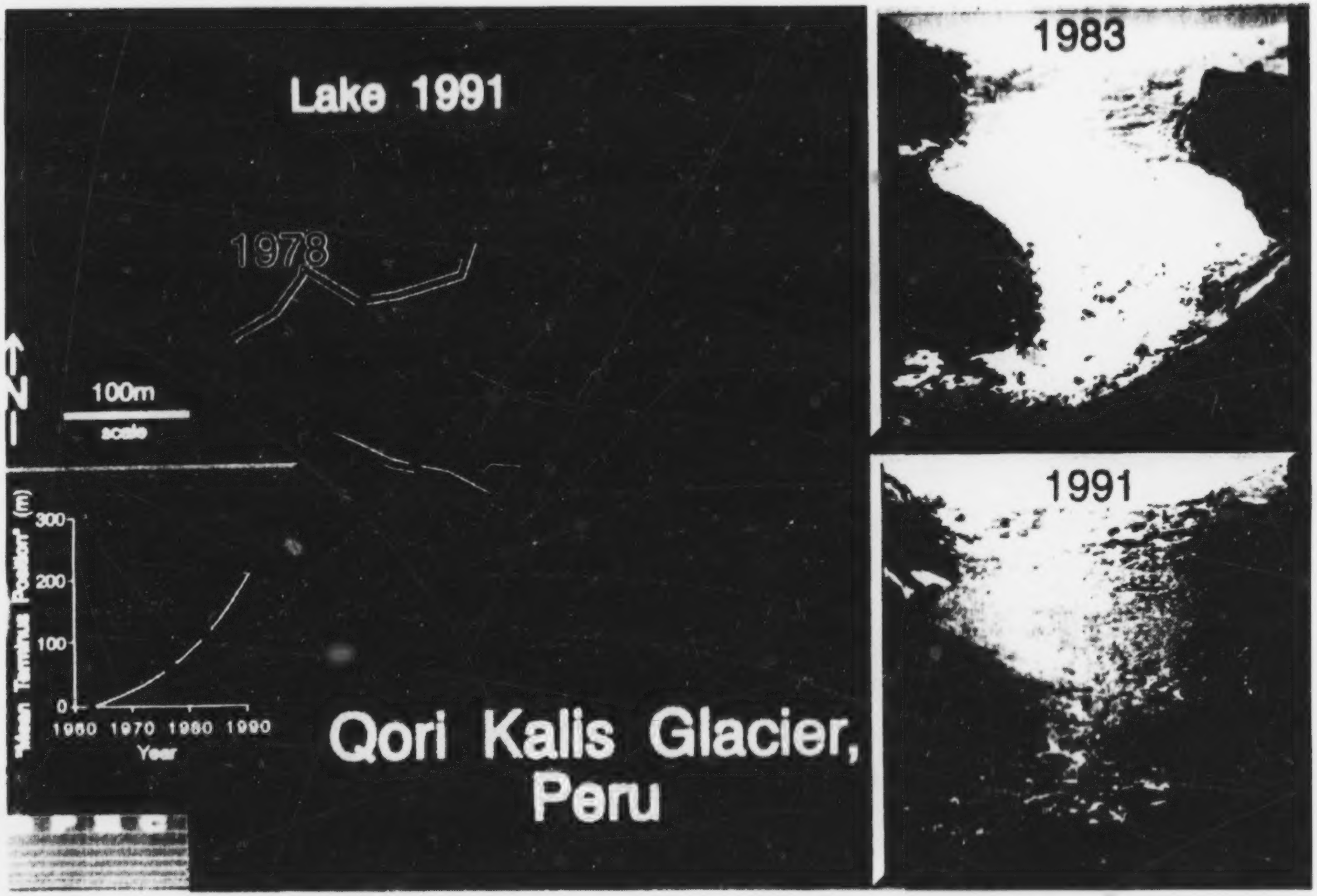
Lake 1991
1978
N
100m
scale
"Mean Terminus Position" (m)
300
200
100
0
1960
1970
1980
1990
Year
Qori Kalis Glacier, Peru
1983
1991

Figure 5. - A composite photograph of the Qori Kalis Glacier from 1983 to 1991. (Source: Dr. L. G. Thompson, Bryd Polar Research Center, The Ohio State University.)

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This activity examines the recording capability of ice found in glaciers, ice caps, ice fields and ice sheets. Drs. L. G. Thompson and E. Mosley-Thompson of the Byrd Polar Research Center, located at The Ohio State University in Columbus, Ohio, are responsible for collecting the data described in this activity. They are well-known glacial scientists who have spent much of their professional lives working on many of the world's ice fields trying to learn about the history of Earth. In the following activities we will examine some of these scientists' research and learn some of the methods they use to collect information about Earth's past. The concepts studied in this activity include *cryosphere; ice cores; climatic records; aerosols, and climatic predictions.*

Objectives: After completing this activity, each student will be able to:

1) describe at least three different types of ice masses (Activities A, C).
2) locate at least three different areas where ice masses exist on Earth's surface (Activities A, C).
3) explain why ice masses exist where they do (Activity A).
4) describe how ice cores can be obtained from ice masses (Activity B).
5) describe how ice cores can yield information about climate (Activity C).
6) examine tropical glaciers to determine the causes of any retreat that is occurring (Activity D).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3, 4, and 5, however, the following ESUs are covered in the Extensions — 1, 6, and 7. Refer to the Framework for ESE for a full description of each understanding.

Activity A: Where are the major ice fields and glaciers of the world?

The two ice-covered polar areas, the Arctic and Antarctica, ice fields, glaciers and areas of permafrost constitute the cryosphere (*cryo* — cold or freezing). Permafrost is an area of subsoil that is permanently frozen.

Materials: a world map with ice formations marked; other world maps and atlases for student reference; Helpful Definitions (at end of this activity).

Procedure:

1) Where on the world map (showing ice features) would a researcher investigate ice fields? Circle these areas.

2) Glaciers form when snow falls in a place where the air temperature is cold enough during the summer to prevent some of the snow from melting. On Earth, summer temperatures are cooler at higher altitudes and latitudes. On the world map, describe where most glaciers are found. Students should encircle these areas and note the elevations on the map.

3) Why do you think glaciers are located in these regions?

4) Locate and name two major ice sheets.

5) Locate at least 3 places where glaciers are found near large, populated regions.

6) Locate 3 places where glaciers are found on or near the equator (within 30° of latitude).

7) What makes it possible for these glaciers to be located so close to the equator?

[These glaciers are at high altitudes.]

8) The Thompsons have been involved with the study of glaciers in many different parts of the world, but they have principally studied the Antarctic ice sheet, the Quelccaya ice cap in Peru and the Dunde ice cap on the Quinghai-Tibetan Plateau in China. Locate and mark these areas on your student map.

Activity B: How are ice cores produced?

One way in which information about an earth system can be recorded is in the ice of glaciers. A core obtained from a glacier contains information about the history of that glacier as well as information about climate and large scale geological events that have affected the glacier.

These **ice cores** are obtained by drilling into the ice of a glacier with various types of drilling equipment. One type of drill is an electromechanical drill. This is a rotary drill which acts like a cork, tree, or soil borer. These drills are usually powered by electric motors using either electric generators, batteries, or solar power. They may also be powered by hand.

A second type of drill is an electrothermal drill which uses an electrically heated cylindrical metal pipe to melt the ice as it moves downward. This is similar to continuously heating a cork borer while pushing it through an ice cube.

The main function of these drills is to cut circular holes deep into the ice so that the central core of ice can be retrieved for further study. Drilling has to stop periodically throughout the project to pull this central core up to the surface. Ice cores are used as sources of data about past climates on Earth. In this activity, the students will produce their own ice cores in the laboratory. (Figure 2 is a photograph of some of the real equipment required to obtain ice cores.)

Materials (for each lab group): large cork borer; bunsen burner; ice cube or ice "sheet"; paper towels.

Procedure:

1) Carefully light the bunsen burner. Put the ice cube on two or three paper towels that are stacked on top of one another. Heat the cutting end of the cork borer near the base of the flame of the bunsen burner for no longer than two seconds.

> **CAUTION: The metal cork borer will conduct heat quickly. Do not heat it for longer than two seconds. Do not put any part of your hand over the hole in the handle end of the cork borer.**

> [Simulated ice cores may be produced by freezing water in 35mm film canisters. To produce dust layers, freeze the water in the canisters 2 cm at a time, and sprinkle pepper, fine sand or graphite between the layers.]

2) Immediately place the heated end of the cork borer on the ice cube (or sheet) and allow it to melt part way into the ice. Heat the end of the cork borer again and put the heated end in the same place on the ice cube (or sheet). Repeat this procedure until you have obtained an ice core that extends all the way through the ice cube (or sheet). Answer Question 3 before your ice core melts completely.

3) Describe your ice core.

4) What difficulties did you have in obtaining your ice core?

> [The cork borer cools off quickly, so it must be heated more than once. Positioning the borer in the same place each time was difficult.]

5) How do you think these difficulties are overcome when scientists take an ice core from a glacier?

> [Scientists use more precise instruments that continuously heat the cutting edge of the coring device.]

6) Describe how you would transport a set of ice cores from a glacier to a laboratory in a warm area thousands of miles from the glacier, without the ice cores melting.

> [The cores would have to be shipped in refrigerated containers.]

7) On a real glacier, would it be possible to obtain one continuous core (in one piece) from the top of the glacier to the bottom? Explain.

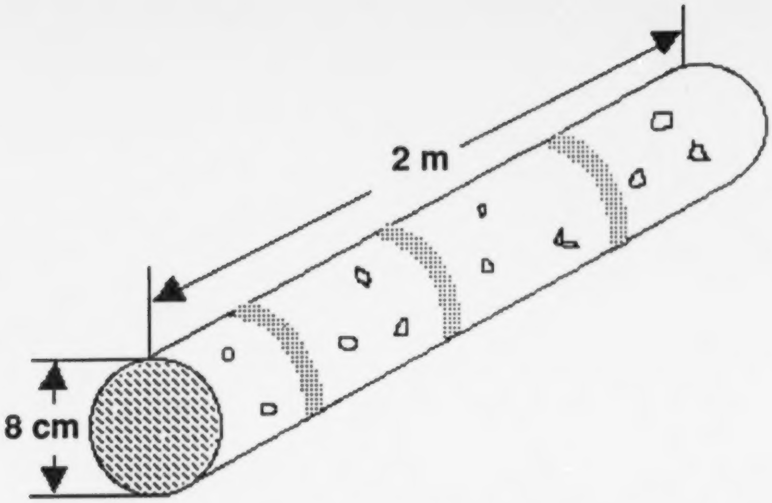

Figure 6. - **Simplified drawing of an ice core, showing the layers of dust representing a number of years.**

Activity C: Frozen Records — What type of information about Earth's past climate is obtained from ice cores?

Just like tree rings, pollen grains in bogs and other types of *proxy data*, valuable information about the Earth's past is stored in glaciers and ice fields. Dust and various other aerosols blown into these areas are frozen in time by falling snow, which eventually accumulates into ice. The dry season (often in summer) is when dust is blown onto the surface of the ice. The dust is then covered by snow during the winter. The snow is then compacted into ice and produces layers (see Figure 1), which become a record of the past climate.

Procedure:

Use Table 1 and your world map to answer questions 1 through 5.

1) Locate and label the study areas in Table 1 on your map.

2) Compare the ice thickness to the elevation of the ice sheet at Vostok in Antarctica. How is the base of the ice related to sea level?

3) What do you think might happen to this area (in Question 2) if the climate became warm enough to melt all of the Antarctic ice?

4) In Table 1, what do the two ice caps have in common?

[The ice caps are both at very high elevations (5,000 meters or above), and they are relatively thin.]

5) In Table 1, what do the four stations located on ice sheets have in common?

[The ice sheets are at high latitudes, and they are relatively thick.]

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Continent	Name	Type	Location	Elev. (m)	Thickness of Ice (m)	Length of Core (m)	Type of Drill
Greenland	Dye 3	Ice Sheet	60° 11' N 43° 50'W	2479	1900.00 2037.63	2037.63	Electromech.
Greenland	Camp Century	Ice Sheet	77° N 61° W	1885	1390.00	1390.00	Electromech. Electrotherm.
Greenland	Crete	Ice Sheet	71° 07' N 37° 19' W	3172	3200.00	404.00	Electromech.
Antarctica	Vostok	Ice Sheet	78° 28' S 106° 48'E	3500	3800.00	2083.00	Electrotherm.
Asia	Dunde	Ice Cap	38° 06' N 96° 24' E	5000	140.00	140.00	?
S. America	Quelccaya	Ice Cap	13° 56' S 70° 50' W	5670	163.60	163.60	Electromech. Electrotherm.

Table 1. - Glacier locations used as study areas to obtain ice cores.

Figure 7A is a drawing of three hypothetical parts of an ice core taken from the Dunde ice cap. Ice cores contain many different types of impurities which allow scientists to learn about the environmental conditions that existed during the formation of the ice fields. The dark bands in these diagrams represent dust layers deposited from the atmosphere onto the snow fields throughout the year. Concentrated layers of dust are usually formed during dry seasons.

This process can be observed on ice fields today. Scientists assume that "the present is the key to the past." That is, modern Earth processes do not substantially differ from those that have existed throughout Earth's history. With this knowledge, scientists are able to use this layering effect as a means of dating ice cores. The distance from one dust layer to the next in an ice core represents the amount of ice that accumulated in one year. Examining Figures 7A and 7B, answer the following questions.

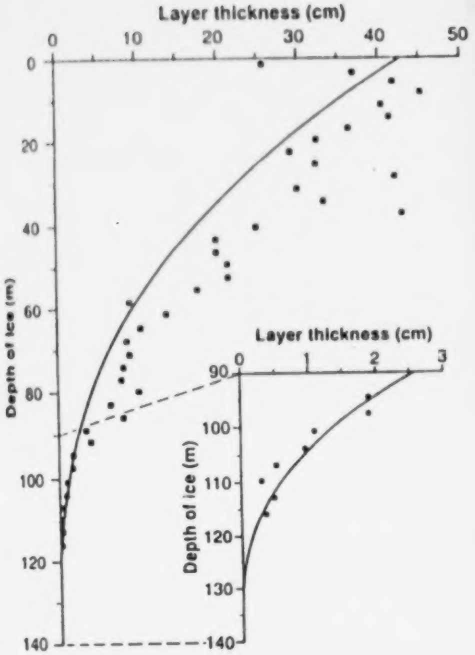

Figure 7B. - Average annual layer thickness based upon the visible dust layers as a function of depth in cores A, B, and C. (Source: *Science*, Thompson et al., "Holocene-Late Pleistocene Climatic Ice Core Records from Qinghai-Tibetan Plateau." 246 (4929) : 474 - 477, October 27, 1989, © AAAS.)

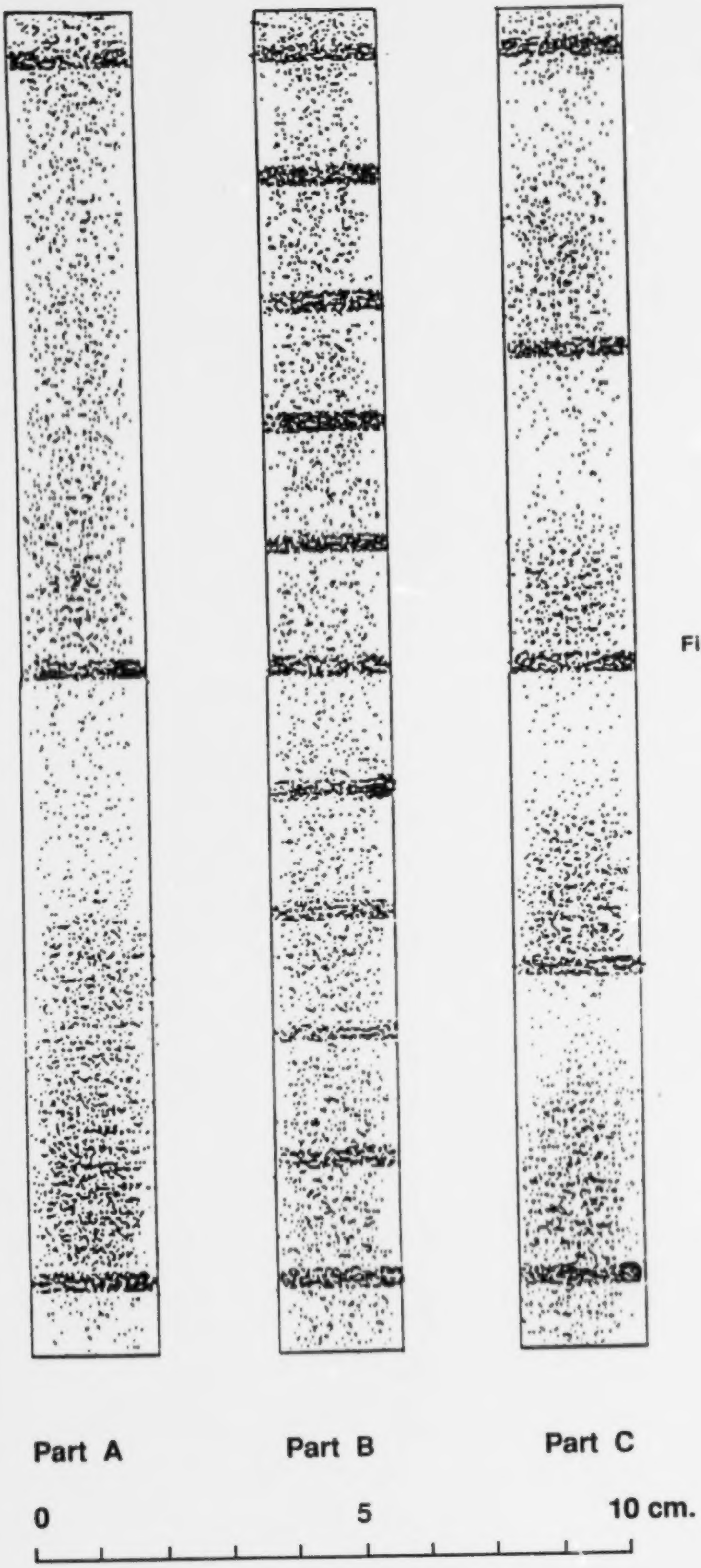

Figure 7A. - Hypothetical ice cores from Dunde ice cap.

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6) How many complete years are represented by each part of the core?

A_____ years B_____ years C_____ years

[2, 10, 4]

7) What is the average thickness of the layers in each part?

A_____ cm. B_____ cm. C_____ cm.

[10, 2, 5]

8) How deep was each part of the core originally found in the ice cap? (Use Figure 7B.)

A_____ m. B_____ m. C_____ m.

[60, 95, 75]

9) State in your own words how the thickness of the layers and the depths of the samples are related.

[The deeper the sample, the thinner the layers.]

10) Hypothesize what might cause such a relationship.

[As the ice gets deeper, the weight of the overlaying ice compresses the ice more and more.]

11) How might you test your hypothesis?

[Answers will vary but should include measures to put increasing amounts of pressure on ice.]

Bands of dust are important in determining the age of ice cores. The composition of the dust and other impurities is equally important to the study of past environments. For example, the amount of lead found in glaciers can be measured. Use Table 2 to answer questions 12 through 15.

Lead is introduced into the atmosphere mainly through the combustion of leaded fuels and from some industrial processes. Small amounts are also added to the atmosphere through natural processes. High amounts of lead are dangerous to human health. It affects the central nervous system and can cause death.

YEAR	LEAD CONCENTRATION (pg g^{-1})
1500 to 5500 BP	6
—	—
1755	12
1815	36
1830	60
1860	38
1875	36
1880	75
1910	65
1935	50
1950	160
1955	120
1960	150
1965	245

Table 2. - Lead amounts in ice cores from Greenland glaciers over a time period. Lead concentrations are given in pg g^{-1} (pg = 10^{-12} per gram of ice). (Source: Adapted from Wolff and Peel, *Nature*, 1985.)

12) Construct a graph from the data in Table 2. Explain what the graph indicates about changes in the amount of lead in our environment.

[The amount of lead has fluctuated some but has generally increased in the last 200 years.]

13) Why you do think the amount of lead has changed over time?

[The amount of lead has changed with the increase in the use of lead in industry and increased use of leaded fuels for cars and other vehicles (until late '70s).]

14) Why should we be concerned about this?

[Lead is a metal that is dangerous to life.]

15) If you were to look at data for lead since about 1975, you would see that the amount of lead in the environment has declined. Explain why this has happened.

[The amount of lead has declined because many people have switched to using unleaded fuel.]

16) List the sources of other types of matter that might be contained in the dust layers of glaciers.

[SO_2 from volcanic eruptions, nuclear fallout from atmospheric testing, soot from oil fires in the Middle East.]

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Activity D: Are glaciers shrinking because of a natural variation in their cycle or from global climate change?

Tropical glaciers are shrinking. Why? The main purpose of Dr. Lonnie Thompson's work is to investigate the reasons behind this phenomenon. Is this retreat part of the regular cycle of the glaciers? Have they gone through this process before? How could he and the other scientists determine what causes this retreat?

> [By creating a historical record of climate from ice cores and meteorological data. This allows scientists to investigate the data for any natural variation, particularly over the last 500 years.]

However, some glaciers are now shrinking so fast that the scientists cannot obtain the information needed to determine a history for that area. Why do you think the rate of melting has increased? In this activity, you will examine evidence that illustrates the retreat of two glaciers in Peru.

Materials: world map with ice formations marked; Figures 3 - 5.

[Transparencies of Figures 3 - 5; overhead projector.]

Procedure:

1) Locate the Quelccaya and Qori Kalis Glaciers on the world map.

2) Figures 3 and 4, photographs of the Quelccaya Ice Field, were taken in 1979 and 1991 respectively. The boulder in the top left corner of the 1979 photograph is located to left of center in the 1991 photograph. Answer the following questions.

   a) Even though the photographs were taken from different angles, what do they tell you about this glacier?

      [The glacier has melted considerably in the last 12 years.]

   b) Describe the appearance of the glacier in the two photographs.

      [The height of the glacier has decreased.]

3) Examine Figure 5, the Qori Kalis Glacier photograph, and answer the following questions.

   a) How much did the glacier retreat between the years 1963 - 1983?

      [Over 100 meters.]

   b) How much did the glacier retreat between the years 1983 - 1991?

      [Over 100 meters.]

c) What does this tell you about the rate of shrinkage?

[The rate of shrinkage has doubled.]

d) Examining the 1983 and 1991 photographs at the right side of Figure 5, what can you say about the size of the glacier?

[Visibly, the glacier has shrunk. The top of the glacier has decreased and the base has thinned.]

e) Examine both sides of Figure 5, paying particular attention to the base of the glacier and the retreat lines of the glacier. What new glacial feature appeared in 1991?

[A lake appeared at the base of the glacier.]

4) The current rate of retreat for tropical glaciers hints at a situation exceeding the normal range of variation. What factors could cause this to occur? Is the evidence conclusive enough?

[Increasing amounts of greenhouse gases released to the atmosphere, natural global warming involved in Earth's glacial cycles are factors that may cause an increase in the retreat rate for tropical glaciers. Future warming that is predicted on a global scale could increase the rate of retreat for these glaciers. Evidence at the present time is not conclusive that enhanced global warming caused by human activity results in an accelerated shrinkage of these glaciers.]

5) Even though tropical glaciers are shrinking, scientists have not yet found the polar glaciers to exhibit this phenomenon. Why do you think this is the case?

6) Scientists predicted that the winter of 1992/93 would be colder because of the volcanic eruption of Mt. Pinatubo. Would this decrease in temperature have an influence on the glaciers' retreat? Would it be a significant impact?

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Evaluation:

Each student should answer the following questions.

1. The Quelccaya ice cap in Peru does not receive much snowfall. Predict if the annual layers in this ice cap are thin or thick. Explain.

2. Describe the kinds of information that can be obtained from layers of dust and other impurities in ice cores.

3. Compare the climate information provided by ice cores to that provided by other **proxy data** forms such as tree rings. Synthesize these ideas and write a general statement about the value of proxy data in analysis of past climates.

4. Alpine glaciers seem to be expanding after retreating for many years. Describe the factors that may contribute to the retreat of tropical and alpine glaciers. How might human activity have accelerated this process.

Extensions:

1) The ice-covered polar areas at the extremes of the globe are vast wastelands, devoid of beauty and life. These flat expanses of ice encrusted land are of little value to anyone. Do you agree with this statement? Produce some evidence to confirm or refute this statement.

2) "Walking in a winter wonderland" is a line from the song *Sleigh Bells*. Have you ever walked in a winter wonderland? Examine one of the northern states or the Canadian provinces and describe how snow and winter conditions affect the ecosystems and living conditions for people. Are there any areas of permafrost in the chosen region? Why (not)? What impact would permafrost have on crop production?

3) Several other planets and moons have ice on their surface or a few meters below the surface. Mars, like the Earth, has polar ice caps which enlarge and shrink with the change in seasons. Examine the formation of the polar ice caps on Mars. How could scientists investigate the past climate of this planet? If ice cores are used, would it be feasible to transport them back to Earth for examination? Have polar ice caps formed on other planets/moons? Why (not)? Produce some evidence for your conclusion.

4) Cryogenics is the study of the effect of low temperatures on the properties of matter. Examine the work of a scientist in relation to cryogenics. Recently, because of the retreat of some alpine glaciers an incredible discovery was made. A frozen 5,300 year old wanderer — the most ancient intact human — was uncovered from his glacial resting-place. Examine this story (Jaroff, et. al., 1992) and compare it to current cryogenics.

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5) Various scientists who work in the Arctic or Antarctic study meteorology, biology, earth sciences and the oceans while in this environment. Describe the work that these scientists perform and its value to people. For various indigenous people, surviving in this cold, harsh environment is a way of life. Describe a typical day in the life of such people. Compare the two groups (scientists and indigenous people) working in the polar region. Is any work of greater value than the other? Why (not)?

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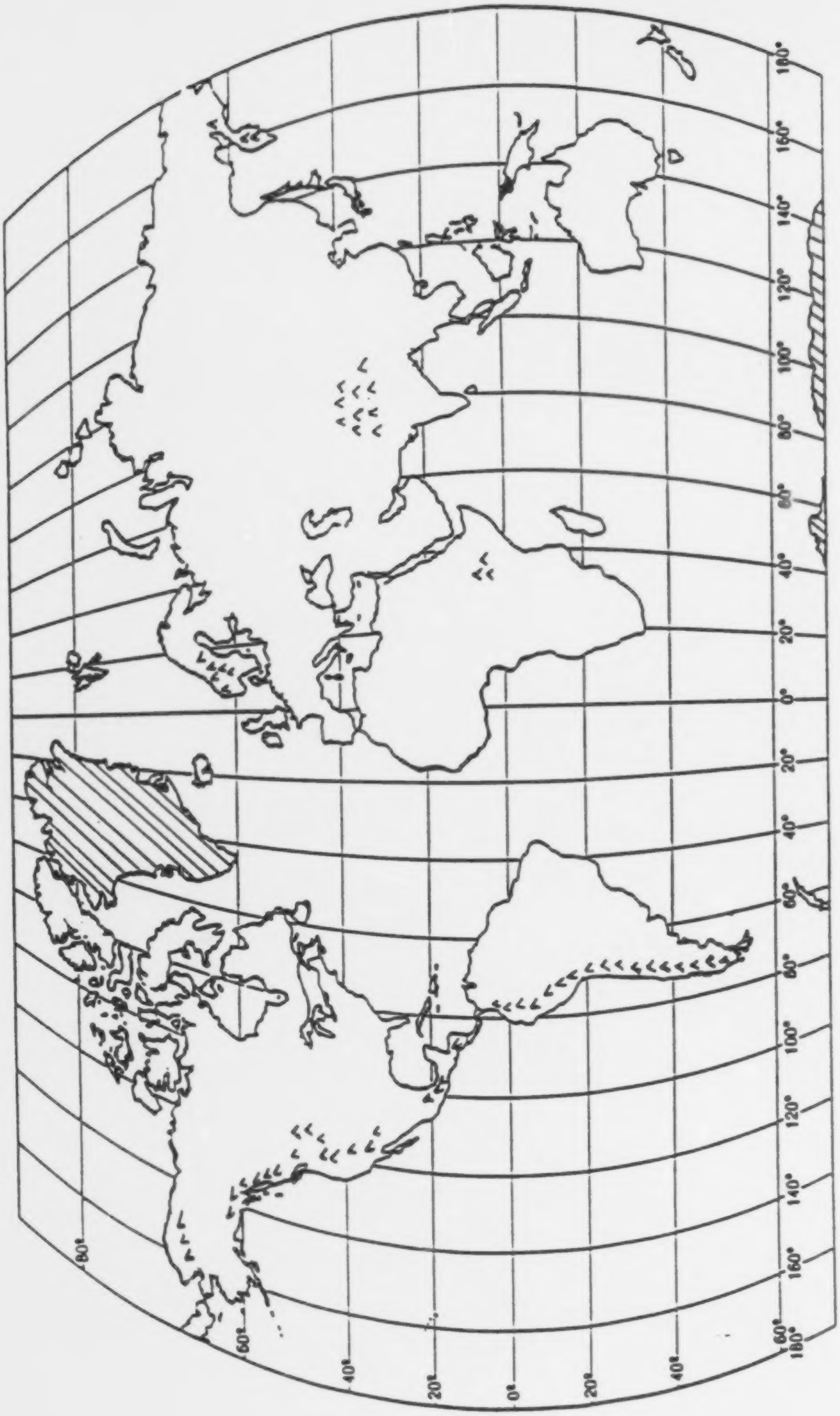

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World map showing locations of major ice formations.

Legend : Shaded areas — ice fields, ^^^ — mountain glaciers.

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Teacher Background Information:

Abramson, R. 1992. "Global Warming." *Marshall Alumnus.* Marshall University Association: Erickson Alumni Center, 400 Hal Greer Blvd., Huntington, WV 25755-6200. p. 20 - 28.
An excellent article that documents the work of Drs Ellen Mosley-Thompson and Lonnie Thompson on ice cores. The article follows their work from obtaining ice cores in Antarctica to the high mountain glaciers of Peru and China. The difficulties involved in obtaining these cores from inaccessible regions of the world is documented. Excellent photographs complement the article. (Also available in the *Los Angeles Times*, dated Saturday, January 4, 1992, pages 1 and A12. However, more photographs are found in the article from *Marshall Alumnus.*)

Hodgson, B. 1992. "Hard Harvest on the Bering Sea." *National Geographic.* 182 (4) : 72 - 103.
This article examines two sides of the fishing industry in the Bering Sea. The large industrialized floating fish factories are compared with the simpler methods used by the indigenous people of the region. It examines how western society is beginning to impact the lifestyle of the native people that inhabit the region around the Bering Sea.

References:

Alley, R. B., and Whillans, I. M. 1991. "Changes in the West Antarctic Ice Sheet." *Science.* 254 November 15, 959 - 963.

Bruemmer, F. 1989. *The Arctic World.* New York: Portland House.

Bockstoce, J. 1990. "Northwest Passage." *National Geographic.* 178 (2) : 2 - 33.

Douglas, B. C., Cheney, R. E., Miller, L. and Agreen, R. A. 1990. "Greenland Ice Sheet: Is It Growing or Shrinking?" *Science.* 248 April 20, 288.

Jaroff, L., Rademaekers, W. and Schoenthal, R. 1992. "Iceman." *Time.* October 26, 62 - 66.

Moore, P., and Hunt, G. 1990. *The Atlas of the Solar System.* New York: Crescent Books.

Thompson, L. G., Mosley-Thompson, E., Davis, M. E., Bolzan, J. F., Dai, J., Yao, T., Gundestrup, N., Wu, X., Klein, L., Xie, Z. 1989. "Holocene-Late Pleistocene Climatic Ice Core Records from Qinghai-Tibetan Plateau." *Science.* 246 October 27, (4929) : 474 - 477.

Wolff, E. W. and Peel, D. A. 1985. "The record of global pollution in polar snow and ice." *Nature.* 313 February, 535 - 542.

VIDEO:

A Co-Production of Maryland Public TV, Film Australia, Wiseman (UK), Electric Image (UK) in Association with Principal Film Company Ltd. (UK). 1990 . *After the Warming.* Forty-five minutes into program 1, "The Fatal Flower," James Burke talks about ice cores and their significance for researchers as data records of the planet's past climate.

HELPFUL DEFINITIONS (VOCABULARY)

Glaciers: Large masses of ice formed on land by the compaction and recrystallization of snow that accumulates into ice. Glaciers creep downslope or outward because of the force provided by their own weight under the influence of gravity.

Ice cap: A dome-shaped or plate-like cover of perennial ice and snow, which covers the summit of a mountain so that no peaks emerge through it, or which covers a flat land mass such as an arctic island.

Ice field: An extensive area of either interconnected glaciers in a mountain region or pack ice at sea.

Ice sheet: A glacier of considerable thickness and more than 50,000 sq. km. in area, forming a continuous cover of ice and snow over the land surface.

VOLCANIC ERUPTIONS

AND

GLOBAL CLIMATE CHANGE

BEFORE

AFTER

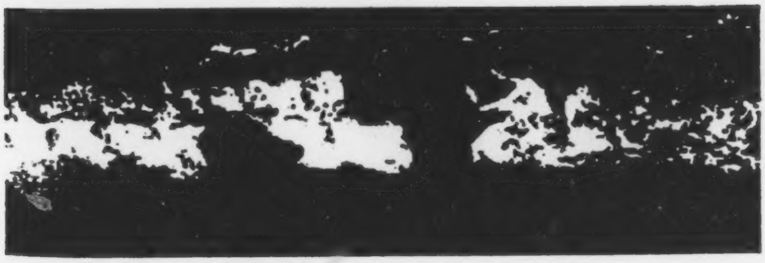

Figure 1. - These images from a U.S. National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellite illustrate the aerosol cloud thrown into the stratosphere by the eruption in June of 1991 of Mt. Pinatubo in the Philippines. As the cloud became more evenly distributed through the stratosphere during the Northern Hemisphere winter, it depressed the mean global temperature by some 0.5°C. (Source: NOAA, 1991.)

When Benjamin Franklin visited Europe in the summer of 1783 he noticed a "dry fog" or haze. He also observed the following winter that Europe was abnormally cold. He suggested that these abnormal weather conditions were the result of volcanic activity. Years later it was discovered that the Laki Volcano in Iceland had erupted in 1783. In 1816, Europe experienced an unusually cool summer and that year was nicknamed the "Year without a Summer." One year before this cool summer, a very powerful eruption occurred on Mt. Tambora in Indonesia.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

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In another instance strange colors and halos around the sun and moon were observed in 1883, along with vivid sunrises and sunsets. These very memorable occurrences followed the most explosive eruption in recorded history, Krakatau in Indonesia, July of 1883. The Krakatau eruption had other global consequences. A loss of 20 - 30% of direct solar radiation for three years followed this explosive event.

The eruption of El Chichon in 1982 in Mexico gave climatologists strong evidence of the potential impact of volcanic activity on global climate change. This eruption, like Krakatau, ejected great quantities of dust, ash, carbon dioxide, and sulfur dioxide high into the stratosphere (Figure 2). Most recently, Mt. Pinatubo, located in the Philippines, erupted several times in June of 1991. This eruption caused spectacular sunrises and sunsets around the world. By mid 1992 it had thrown out twice as much volcanic dust and aerosols as El Chichon.

Large volcanic eruptions cause short-term cooling of the climate. If the climate were in a warming trend at the time of the eruption, the eruption might merely slow the process and no cooling effect might be detectable.

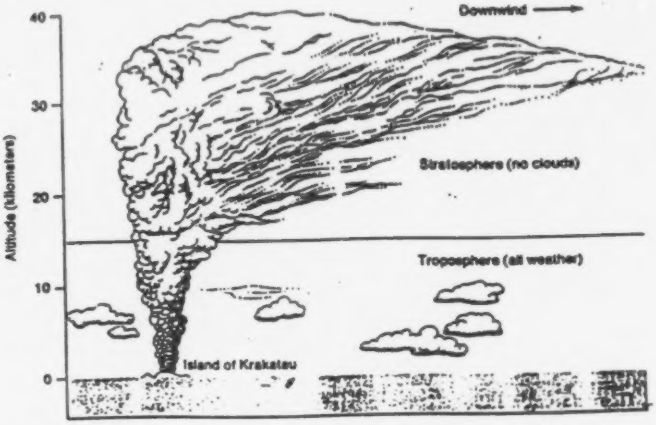

Figure 2. - The Krakatau cloud of 1883 was injected high into the stratosphere. (Source: Decker and Decker, *Volcanoes*, 1989.)

Once all of the volcanic dust and aerosols are injected high into the atmosphere, upper level winds and global pressure systems can circulate this material around the Earth. Volcanic aerosols, in particular sulfur dioxide, can block incoming solar radiation and reduce global surface temperatures for up to two to four years following the eruption (Figure 3). The concepts studied in these activities include: *volcanic emissions; aerosols; global temperature change and acid precipitation.*

Objectives: Upon completion of this activity, students will be able to:

1) locate major volcanoes around the world using latitude and longitude (Activity A).
2) explain how the latitudinal location of a volcanic eruption may affect global climate conditions (Activity A).

3) use the Volcanic Explosivity Index (V.E.I.) to predict the potential of a volcanic eruption to affect global climate change (Activity A).
4) describe the effect of acid precipitation from volcanoes on various materials and environments (Activity B).
5) examine the influence of wind currents on aerosol distribution and its consequences (Activity B).

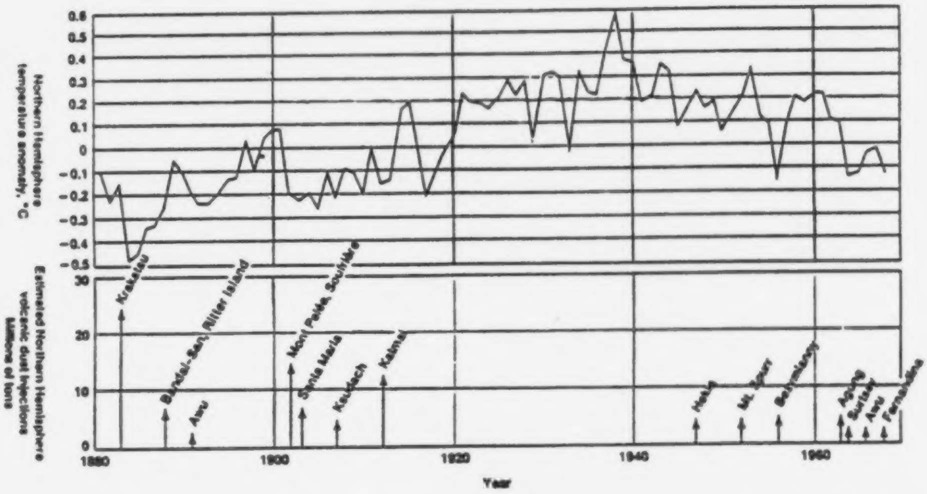

Figure 3. - Graph of average temperature variations after major volcanic eruptions. (Source: Oliver, *Journal of Applied Meteorology*, 1976.)

Earth Systems Understanding (ESUs): This activity focuses on ESUs 3 and 4. However, the following ESUs are covered in the Extensions — 1, 5, 6 and 7. Refer to the Framework for ESE for a detailed description of these understandings.

Activity A: Where and when have recent volcanic eruptions occurred?

Volcanic eruptions differ. Some eruptions produce great quantities of dust and aerosols, while others produce just lava. As a result, not every volcanic eruption can produce significant global climate changes. Some of the significant characteristics needed for an eruption to affect global climate conditions include the latitude of the volcano, the season of the year it erupted, the height of the eruption, and the type and quantity of gases produced.

Materials: large physical wall map of the world; a blank 8 1/2" X 11" map of the world with latitude and longitude lines; library resources or a computer data base for information on volcanic eruptions (see reference list at the end of the activities).

Procedure:
1) Using Table 1 and the blank 8 1/2" X 11" map of the world, locate by latitude and longitude each of the volcanoes listed in the table.

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2) Label each volcano with its name, its elevation above sea level, and the date of the eruption on the map.

3) When you have completed locating the volcanoes you will notice the lack of volcanoes in the Southern Hemisphere. What possible explanation is there for this observation?

4) Climatologists have theorized that only low latitudinal volcanic eruptions, between 20° N and 20° S, can significantly affect global climate conditions. What is the possible basis for this theory?

[The volcanoes listed in Table 1 were selected at random. The intent is to give an even distribution of V.E.I. between the values of 4 and 6.]

Location	Elev. (m)	Lat.	Long.	Date	V.E.I.
Krakatau, Indonesia	0813	6.1S	105.42E	08 1883	6
Pelee,West Indies	1397	14.8 N	61.17 W	05 1902	4
Santa Maria,Guatemala	3772	14.8 N	91.55W	10 1902	6
Ksudach, Kamchatka	1079	51.8 N	157.52 E	03 1907	5
Katmai, Alaska	0841	58.3 N	155.16 W	06 1912	6
Katla, Iceland	1363	63.6 N	19.03 W	10 1918	4
Komaga-take, Japan	1140	42.7 N	140.68 E	06 1929	4
Agung, Indonesia	3142	8.3 S	115.51 E	03 1963	4
Taal, Philippines	0400	14.0 N	121.00 E	09 1965	5
Mt. St. Helens, U. S. A.	2549	46.2 N	122.18 W	05 1980	5
El Chichon, Mexico	1060	17.3 N	93.2 W	03 1982	5

Table 1. - Data from eleven major explosive volcanic eruptions.

Another significant variable affecting the impact of an eruption on global climate change is the power of the volcanic eruption and the direction of the blast. Some volcanic eruptions are extremely explosive and can inject material high into the stratosphere. Volcanologists have developed a Volcanic Explosivity Index (V.E.I.) to compare eruptions. Volcanoes are rated from 0 to 8, where 0 is the least explosive and 8 the most explosive.

5) Arrange the data provided in Table 1 in different ways. Sort the volcanoes by their V.E.I., arrange by latitude and determine if a correlation exists; sort by V.E.I., arrange by longitude and investigate for any correlation; sort by V.E.I., arrange by date and examine any correlation, etc. Continue this process until all the variables have been examined in relation to each other.

[If computers are available to the students, they should produce a database of the information provided in Table 1. The arrangement of the data should follow that outlined above.]

6) From the information in Table 1 (and the database), which volcanoes could have the greatest effect on global surface temperatures?

7) Many climatologists have criticized the V.E.I. because it does not accurately assess some of the important aspects of a volcanic eruption. Considering global change, what characteristics of an eruption does the V.E.I. not take into account?

Activity B: Do volcanic eruptions have an impact on global climate and atmospheric conditions?

Volcanic eruptions can affect global surface temperatures by producing sulfur dioxide gas. Sulfate particles can backscatter incoming radiation warming the stratosphere, thus reducing the amount of incoming radiation effectively cooling the troposphere. (Figure 3 illustrates the cooling effect of volcanic particulates from major eruptions.) Sulfates eventually precipitate out of the stratosphere. An excellent record of sulfate concentrations is found in ice cores from the Antarctic and Greenland ice sheets. These sulfate ice core records are a source of information to help reconstruct past explosive volcanic eruptions and their effect on global climate change.

When great quantities of sulfur dioxide are released by a large volcanic eruption, the gas will oxidize in the stratosphere and combine with water vapor to produce tiny particles of sulfuric acid (Figure 4). This process takes about one month and the particles have a lifetime of three years. The chemical reaction is as follows:

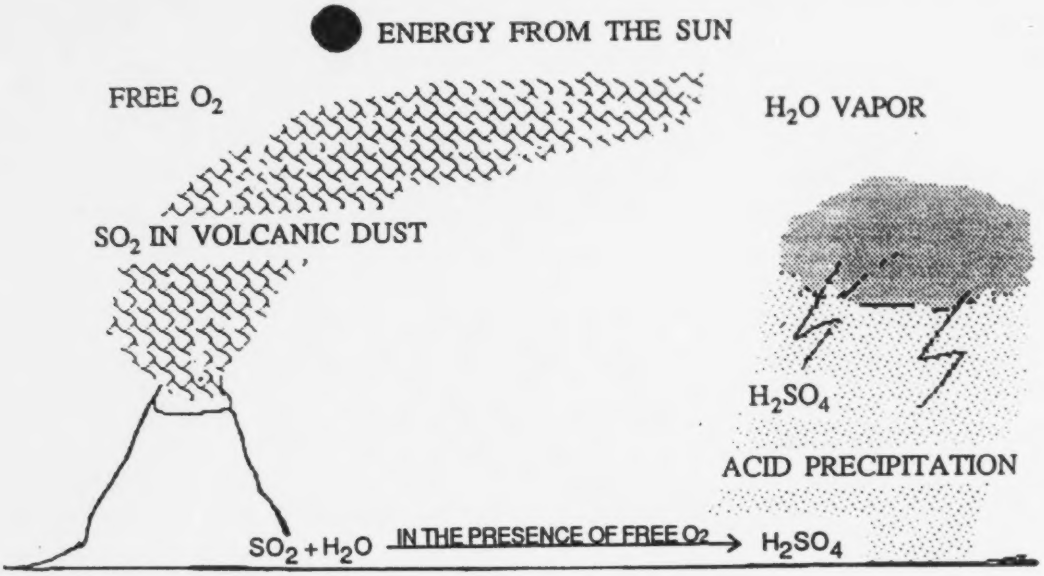


Figure 4. - A diagrammatic representation of the chemical process that occurs when SO_2 is oxidized (in the presence of free O_2) and combines with H_2O vapor to produce H_2SO_4. Energy for this chemical process comes from the sun.

During the time that this process occurs, the sulfur dioxide particles are carried on wind currents, with the result that sulfuric acid precipitation may fall in regions quite distant from the site of the eruption. This creates an additional problem in the form of acid precipitation and its influence on different environments. In this activity, the students will test various materials with a sulfuric acid solution, recording and analyzing the results. Discussion can relate these results to volcanic eruptions.

Materials: copy of Figure 1; 4 ml of 1 molar sulfuric acid to prepare 2 liters of acid rain solution pH 3 - TO BE PREPARED BY THE TEACHER; data sheet; various materials to be tested such as different types of rocks (limestone, sandstone, basalt, etc.) soil, metals, water, etc.; filter papers; 1 clear plastic cup 9 oz. capacity; rubber bands; some Universal Indicator solution; some distilled water; droppers.

Procedure:

1) Divide the class into groups, with at least 4 students per group. Each group should receive a set of materials to conduct the experiments.

2) **REMIND STUDENTS OF THE APPROPRIATE SAFETY CONSIDERATIONS.** A few drops of acidic solution is placed on the surface of the different rocks and metals. Have students describe the results on the data sheet.
  - Did all the materials react the same? If so, why? If not, why not?
  - What influence would this have on stone buildings? Are there any commercial uses for this effect? What are they?
  - What influence would this have on metal structures? Are there any commercial uses for this effect? What are they?

3) The students should test the pH of water from natural sources, like streams, rivers, ponds and lakes, with the Universal indicator. Each group should test water from a different source in this manner.
  - Place 4 ml of indicator in the plastic cup. **(REMIND STUDENTS OF THE APPROPRIATE SAFETY CONSIDERATIONS).** Add 10 ml of the water samples to the cup. Each group should record the results on the data sheet. Each group should inform the remainder of the class of the results.
  - Now add 10 ml of the acid rain solution to the water. Note the results for each water sample. How has the pH value changed?
  - What impact would this pH change have on the organisms that live in this water? How would it impact a food chain based on these aquatic organisms?

4) The students then should test soil samples from different sources as follows:
  - Place the cup on white paper. Place some soil on the filter paper. Add three drops of Universal Indicator to the cup. Suspend the filter paper containing the soil over the cup and secure it with the rubber band. Pour 5 ml of distilled water onto the soil sample, allowing the water to flow through the soil and drip into the cup. Record the resulting pH of the liquid in the cup.

- Repeat this procedure with a new soil sample and 5 ml of acid rain solution. Record the resulting pH of the liquid in the cup.

  [All results should be shared with the class and recorded on the data sheets.]

- What impact does the acid rain have on the soil samples? What impact would acid rain have on the microorganisms in the soil? What influence would acid precipitation have on the vegetation rooted in this soil?
- What do you think would happen to the pH of water runoff from soil that now experiences acid precipitation? This water runoff would eventually reach an aquatic environment. List the possible impacts this water may have on this type of environment.

5) Examine Figure 1, and explain how the Mt. Pinatubo eruption might influence environments near the eruption site through acidic precipitation. What impact could acidic precipitation from this eruption have on other countries?
   - What type of data would be most useful to climatologists in order to prove that this volcanic eruption could affect global climate conditions? Analyzing the data from Table 1, predict which volcanoes would have the most/least impact on the global climate. Why? Correlate your predictions with the data in Figure 3.

   - Is there any way this evidence could be masked or hidden by other global climate events? In the short term, how might volcanoes influence climate? How could this impact on the climate and weather affect the public's understanding of global warming/change?

6) What are some additional sources of SO_2 and other aerosols? What impact would these have in comparison to volcanic emissions? Which are easier to control? Why?

Evaluation:

On completion of this activity, the groups should create a concept map, showing how the volcanic eruption may influence other environments on a global scale. The various concept maps should be discussed and a class concept map may be produced by the teacher on the chalkboard.

[Refer to page 187 for an example of a concept map on deforestation.]

Extensions:

1) Volcanoes have been represented in many ways throughout the development of human cultures. Some believed volcanic eruptions signaled a god's anger or displeasure with people. Some cultures even sacrificed people to the volcanoes in an attempt to appease them. Vivid sunrises and sunsets have resulted in local areas and globally for many years, following an eruption. Select one of these points and investigate how different cultures have represented or recorded volcanoes and their activity. How do we record such events today?

2) Describe how and why volcanoes occur and their role in the evolution of this planet. How have scientists helped us to understand volcanoes? Investigate the scientists who first helped us recognize volcanoes as part of the Earth's evolutionary process, and how recent technology has aided us in appreciating the processes involved.

3) Have volcanoes occurred on other planets in our solar system? If so, on what planet(s) have they occurred? Do they still exist? How can we improve our knowledge of the volcanic processes by examining other planets? Could they help us unlock further knowledge concerning the formation of this planet? How? Give evidence to support your answers.

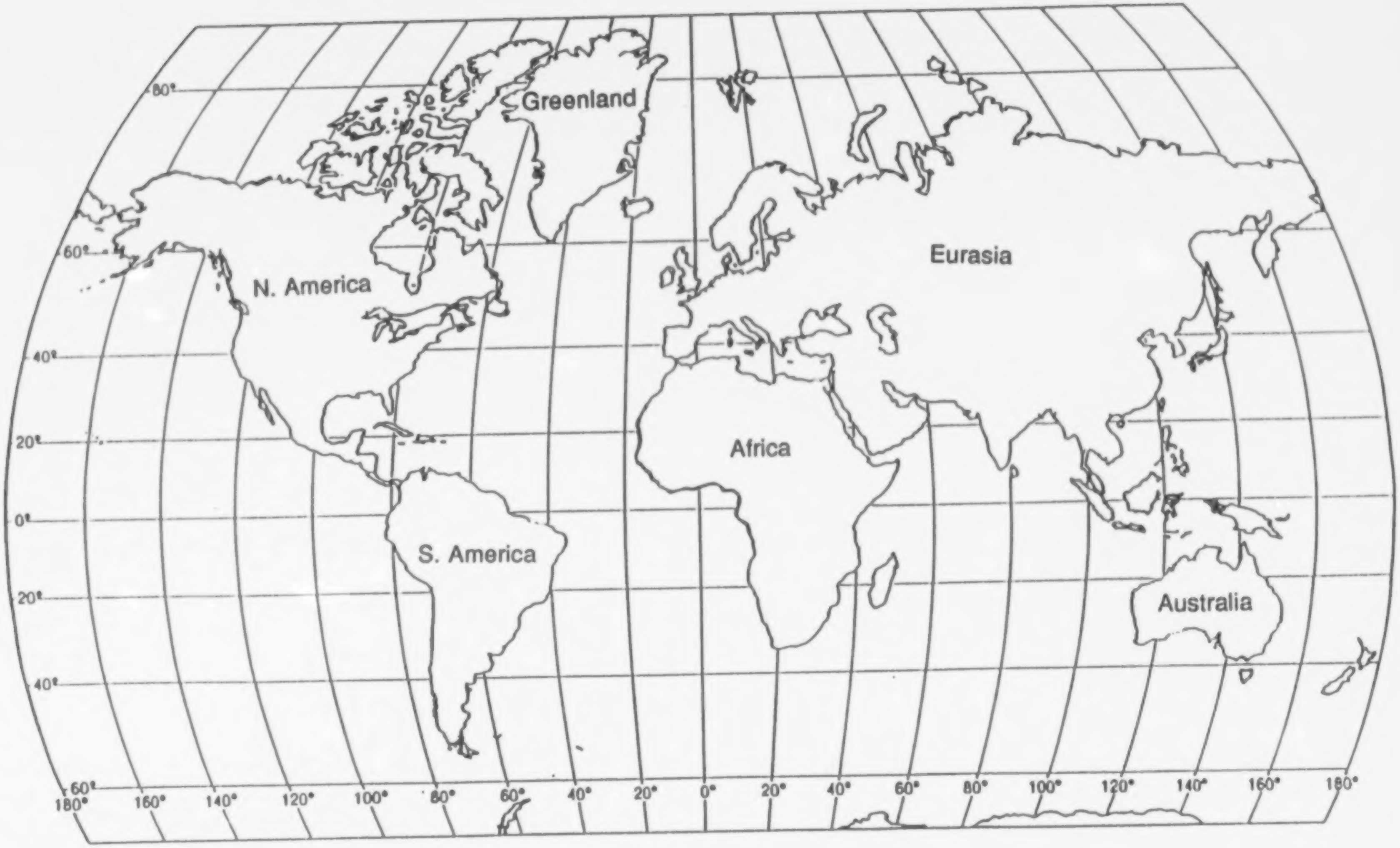
> [The technology fact sheet on GIFs gives information on how to capture NASA photos of other planets. The plots of Jupiter's moon Io clearly show a volcano on the right side of the image.]

4) Volcanologists, soil scientists and geologists study various Earth processes. What other categories of scientists could be involved in studying the elements in this activity? A volcano has erupted in Alaska. As Governor of the state, you must send a team of scientists and other people (engineers, etc.,) to study the volcano and its effects on the area. List the kinds of people you would send; give reasons for your selection. Some of the reasons should relate to their training and expertise.

5) Sulfur dioxide is a dangerous emission from volcanoes. Examine the health risk from this aerosol to a human population. Other aerosols are also emitted during volcanic eruptions. What are these and how do they influence:

   a) the health of a human population?
   b) the health of the natural environment?
   c) acid precipitation and its consequences?
   d) global climate?

6) Examine landscape paintings of famous 19th century artists such as Bierstadt. Is there any evidence of the Krakatoa eruption in any of these paintings? How is this visible? Is there any evidence in other paintings or non-scientific literature from this time that corroborate the effects of the eruption.


Greenland
N. America
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Africa
S. America
Australia
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180°

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Data sheet to record the reactions of different substances - rocks, metals, water and soil - to Sulfuric Acid (H_2SO_4).

			pH	
SUBSTANCE	DESCRIBE REACTION	SUBSTANCE	BEFORE	AFTER
ROCKS: 1.		WATER SAMPLE: STREAM		
2.		RIVER		
3.		POND		
OTHER(S)		LAKE		
METALS: 1.		SOIL SAMPLE: WOODLAND		
2.		FIELD		
3.		WETLAND		
OTHER(S)		OTHER(S)		

Teacher Background Information:

Hocking, C., Barber, J., and Coonrod, J. 1990. *Acid Rain —Teacher's Guide.* Lawrence Hall of Science, University of California, Berkeley, CA. 94720.
A great source of activities on acid rain and a possible starting point for a unit on this problem, particularly human influenced acid precipitation.

Kerr, R. A. 1992. "Pinatubo Fails to Deepen the Ozone Hole." *Science.* 258 : October 16, 395, and 1989. "Volcanoes Can Muddle the Greenhouse." *Science.* 245 : 127 - 128.
Two excellent accounts of the influence of volcanoes on climatic conditions.

Tilling, R. I. 1986. *Volcanoes.* U. S. Department of the Interior/Geological Survey, Federal Center, Box 25425, Denver, CO 80225.
A booklet describing different types of volcanoes and various important volcanic eruptions. A great guide for the novice volcanist.

References:

Bradley, R. S. 1988. "The Explosive Volcanic Eruption Signal In the Northern Hemisphere Continental Temperature Records." *Climate Change.* 12 : 221 - 243.

Decker, R. and Decker, B. 1989. *Volcanoes.* New York: W. H. Freeman and Company.

Hoblitt, R. P. 1986. *Observations of the Eruptions of July 22 and August 7, 1980, at Mount St. Helens, Washington.* U. S. Geological Survey Professional Paper 135. U. S. Government Printing Office Washington D. C. 20402.

Mass, C. F., and Portman, D. A. 1989. "Major Volcanic Eruptions and Climate: Critical Evaluation." *Journal of Climate.* 2 : 566 - 592.

Nash, J. M. 1991. "What Makes them Blow." *Time.* June 24, 42 - 44.

National Oceanic and Atmospheric Administration. 1991. Satellite images of aerosol cloud thrown into the stratosphere by the eruption of Mount Pinatubo.

Oliver, R. C. 1976. "On the Response of Hemispheric Mean Temperature to Stratospheric Dust: An Empirical Approach." *Journal of Applied Meteorology.* 15 (9) : 933 - 950. (Graph available on p. 934.)

Sear, C. B., Kelly, P. M. and Jones, P. D. 1987. "Global surface-temperature responses to major volcanic eruptions." *Nature.* 330 : 365 - 366.

Self, S., and Rampino, M. R. 1988. "The Relationship Between Volcanic Eruptions and Climate Change: Still a Conundrum?" *EOS.* 69 (6) : 74 - 86.

HOW HAVE ALL THE SPECIES GONE?

A great deal of controversy swirled about the scientific world in the decade of the 1980's regarding a theory for the extinction of the dinosaurs and other life forms. It even entered the political arena through congressional testimony from scientists such as Carl Sagan and Stephen Jay Gould who held that the theory had implications for nuclear war and the survivability of all life forms including humans if such a war should break out. The theory is an excellent example of the cooperation of scientists from disciplines as diverse as biology, chemistry, geology and physics in arriving at a theory that addresses the data found in rocks throughout the world.

Hey!!!!!! where did everybody go?

This activity examines theories for the mass extinction of life forms and how they apply the evidence found in the geological record. Additional concepts studied include: *adaptive radiation; stasis; evolution and nuclear winter.* Much of the work is done in cooperative learning groups. The activity is intended for use in the senior high school in biology, earth science, chemistry or integrated Earth Systems courses.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with the support of The Ohio State University.

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Objectives: When the students have completed this activity, they should be able to:

1) relate the development of dinosaurs to the Earth's history (Activity A).
2) describe the concepts of mass extinctions, background extinction, punctuated equilibrium and stasis (Activity B).
3) interpret the possible causes of mass extinctions using geological evidence presented in science literature (Activity C).
4) analyze the past and present rates of extinctions (Activities B and D).
5) identify human and natural environmental reasons for extinctions (Activity D).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 1, 2, 3, 5 and 6. However, the following ESUs are covered in the Extensions 1, 4 and 7. Refer to the Framework for ESE for a full description of each understanding.

Materials: a VCR and TV; *Fantasia*, the video.

Activity A: How did the dinosaurs live?

In this activity a segment of the classic movie, *Fantasia*, is used to review the development of the earth and its life forms, and to introduce the extinction of the dinosaurs, a central topic for this activity.

In the movie, the Disney artists provide a unique interpretation of Igor Stravinsky's **"The Rite of Spring."** It begins at 40 minutes into the commercially available video and lasts for twenty minutes.

Procedure:

1) Play the segment for your students. Suggest that they listen to the music to see if they can correlate sounds and instruments with events depicted on the screen.

2) Divide the class into groups of three or four students each. Play the section of the tape a second time. Assign different students in each group the responsibility of recording information about each of the following:
   a) description of the events in the evolution of each of the Earth systems depicted in the tape;
   b) identification of the life forms in each segment and especially the different types of reptiles depicted in the dinosaur segment;
   c) description of the ways in which the music and art enhance the story depicted on the screen. If you have assigned four students in a group, two of them can divide this task. One can focus on the music of the video and the other can focus on the art.

3) Have students within each group discuss their observations and develop a group report on the video segment.

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4) Conduct a class discussion starting with a representative of each group presenting the group's report to the class. The class discussion should focus on differences in observations, interpretations and analyses between the various group reports.

5) This movie was produced over 50 years ago. Have your students determine the degree to which current scientific thought agrees or disagrees with that depicted in the movie. They should especially address the following:

   a) how the earth, the atmosphere, the water in the oceans were thought to form;
   b) the "life style" of the dinosaurs;
   c) the probable cause for the extinction of the dinosaurs.

   [It is interesting to note that the behavior of the dinosaurs as depicted in the movie was widely criticized by the scientific community at the time. It was thought that dinosaurs were slow, lumbering solitary creatures of very low intelligence. However, recently, paleontologists have found evidence that certain species had a herding instinct, that family groups stayed together for years, and that some were very active, speedy creatures; much as they are depicted in the film.]

   [It might be interesting, at the beginning of this activity to show a segment of a movie which contains humans and dinosaurs in the same scenes. A movie such as *The Land that Time Forgot* has many such scenes. Ask your students to compare the two movies and consider which one is more scientifically correct? Does the fact that one is animated make it any less scientific?]

Activity B: How and why do organisms become extinct?

Materials: two sets of cards — each with about 20 illustrations of animal species; one set should consist of illustrations of species of animals from the Mesozoic; the other set should have illustrations of species of animals from the Cenozoic; a clock with a sweep hand.

[Use the references at the end of this activity as sources of pictures. Try to have a balance of marine and terrestrial animals in each set.]

Procedure:

1) Number the cards in the Mesozoic set as follows:
   a) individually 1 through 7;
   b) all remaining cards with the same number, 8.

2) The Cenozoic cards should be numbered sequentially, 1 through 20.

3) Prepare enough duplicates of cards in each set so that every student in class can receive a card from each set.

4) You should also have a clock with a sweep second hand visible to all students in the room.

Preparation for simulation

5) Hand out the Mesozoic set of species cards to students. Have students do some background research on their particular animals.

6) Spend part of a class having students describe their animals to the remainder of the class.

7) If students haven't dealt with large numbers before, you might have them do the activity *How long is long ago?* by Dan Jax. This is listed in the reference section at the end of this activity.

Simulation

8) Have one student volunteer to be the 'extincter.' Explain to the class that the movement of the hands on the clock will represent the passage of geologic time. One minute will equal six million years.

9) Ask students to stand beside their desks holding their Mesozoic cards so that other students can see what species they represent.

10) Have the 'extincter' call out card numbers 1 through 5 at 30 second intervals. The student or students holding these numbered card(s) are to sit down thus representing the removal of that species from the Earth.

11) At the end of the third half–minute (9 million years) ask the class to explain the process this represents (*background extinction*). Have them determine the rate of background extinction.

> [One per 3 million years – the actual rate estimated over the past 600 million years is about one species per year.]

12) At the end of the fourth half–minute (12 million years) ask the class whether there have been any other changes among the population of animals over the past 15 million years?

> [No].

Discuss the concept of *stasis* .

> [Little change in populations over long periods of time].

13) At the end of the fifth half–minute (15 million years) have the 'extincter' call number 8 (*a mass extinction event*). All but two of the remaining species will now be

sitting (*extinct*). Discuss possible causes of such a mass extinction.

14) At the end of the sixth half-minute (18 million years) have one of the remaining species sit down (continuation of background extinctions). Immediately give all seated students new species cards from the Cenozoic set of cards. Have them stand.

15) Have the 'extincter' continue background extinctions every half minute starting with number 1, while you discuss *adaptive radiation* with the students and review the concepts of stasis, mass extinction and background extinctions.

16) Summarize by discussing the concept of *punctuated equilibrium* as a mechanism for evolution of species.

> [The idea of punctuated equilibrium arose through studies by Eldredge and Gould as documented in Eldredge's book, *Time Frames*. Instead of evolution proceeding at a slow constant rate they presented considerable evidence over the years that very little evolution would proceed during "normal times." There would be a slow rate of background extinction with a few new species arising from mutation (stasis). Eventually there would be a dramatic change in the environment with many species becoming extinct. This would be followed by a rapid development of new species adapting to and radiating into the now vacant habitats (adaptive radiation). And once again, stasis would exist as long as there were no dramatic environmental changes. Although controversial at first, this concept of evolution has been widely accepted by the scientific community. The mass extinction process, the focus of this activity, provides a mechanism for dramatic environmental changes and therefore fits very well the theory of punctuated equilibrium.]

Activity C: What theories explain mass extinction?

Procedure:

1) Divide the class into six (three or four member) cooperative learning groups. Each group will develop one of six different topics. They should study several of the documents suggested for the topic and develop a short presentation.

2) Assign the following roles to students in each group:
   a) the team leader who will represent the group during the panel discussion that culminates the activity;
   b) the literature researcher who will assist the team in finding additional information, and in helping to interpret the articles provided.
   c) the graphics designer who will be responsible for locating and designing graphics to be used in the panel presentation.

3) All team members will be responsible for studying information on the topic and suggesting what is included in the presentation.

Research Topics

A) What evidence is there for meteorite impact as the cause of mass extinctions (The Alvarez hypothesis)? In 1980 a team of researchers from the University of California - Berkeley, announced evidence they had pieced together, suggesting that a large meteorite had impacted the Earth at the end of Cretaceous time possibly causing the extinction of the dinosaurs and many other life forms. Key evidence included very high levels of iridium, an element thought to be found primarily in extraterrestrial sources, in sediments at the top of the Cretaceous.

Resources:
a) Demise of the dinosaurs: A mystery solved? Robert S. Dietz. *Astronomy*. July 1991, 30 - 37.
b) Cretaceous ground zero. Alan R. Hildebrand and William V. Boynton. *Natural History*. June 1991, 47 - 52.
c) Mass extinctions caused by large bolide impacts. Luis V. Alvarez. *Physics Today*. July 1987, Vol. 40, 24 - 33.
d) An extraterrestrial impact. Walter Alvarez and Frank Asaro, *Scientific American*. October 1990, 78 - 84.
e) Mass extinctions: Volcanic, or extraterrestrial causes, or both? Ben Patrusk. *Oceanus*. Fall 1987, 40 - 48.

B) What is the theory of punctuated equilibrium? What evidence supports that theory? When observing the fossil record it appears that assemblages of animals and plants remained very similar for long periods of time. It also appears that the environment in which they lived remained constant over the same period of time. Changes in populations seemed to have occurred rapidly and to have been accompanied by changes in the environment. This evidence caused two researchers, Stephen Gould and Niles Eldredge, to suggest that evolution proceeded sporadically, in large part resulting from sudden environmental changes.

Resources:
a) *Time Frames*. Niles Eldredge. 1985. Simon & Schuster, Inc.
b) Progress in evolution? Niles Eldredge. *New Scientist*. June 5, 1986, Vol. 110, 54 - 57.
c) The view of life: Opus 200. Stephen Jay Gould. *Natural History*. August 1991, 12 - 18.
d) Overview: punctuated equilibrium. Tim Beardsley. *Scientific American*. Vol. 262, March 1990, 36 - 38.
e) Punctuated equilibrium is now old hat. Roger Lewin, *Science*. Vol. 231, February 14, 1986, 672 - 673.

C) What evidence is there in the fossil record for a periodicity of mass extinctions? When examining the fossil record paleontologists have found that there seems to be a recurrence of mass extinctions every 26 million years or so. What type of process could cause the periodicity of mass extinctions? Some astronomers have suggested that there might be a companion star that periodically distorts the gravitational field of

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the Sun and thus changes the orbits of meteorites, causing "meteorite showers" on the Earth.

Resources:
a) The evidence: Cycles of extinction. Shannon Brownlee. *Discover.* May 1984, 22 - 24.
b) The theories: Cosmic winter. Dennis Overbye. *Discover.* May 1984, 26 - 29.
c) Extinctions or which way did they go? Steven Stanley. *Earth.* January 1991, 18 - 27.
d) Periodic impacts and extinctions reported. Richard A. Kerr. *Science.* March 23, 1984, 1277 - 1279.
e) Mass extinctions in the ocean. *Scientific American.* Vol. 250, June 1984, 64 - 72.
f) Extinctions: A paleontological perspective. David Jablonski. *Science.* Vol. 253, August 16, 1991, 754 - 757.

D) What implications did the meteorite impact theory have for the world debate on nuclear war? The types of climate changes proposed to cause extinctions are thought to be likely in the event of an all-out nuclear war. Scientists began discussing the concept of *Nuclear Winter* and the devastating impact it could have on the world population.

Resources:
a) An ancient "nuclear winter." Sharon Begle. *Newsweek.* October 14, 1985, 106.
b) Extinction wars. Stefi Weisburd. *Science News.* Vol. 129, February 1, 1986, 75 - 77.
c) The climatic effects of nuclear war. R. Turco, O. Toon, T. Ackerman, J. Pollack, and C. Sagan. *Scientific American.* August 1984, Vol. 251, 33 - 43.
d) After nuclear war: A nuclear winter. Laura Tangley. *Bioscience.* Vol. 34, January 1984, 6 - 9.
e) Climate and smoke: An appraisal of nuclear winter. R. Turco, O. Toon, T. Ackerman, J. Pollack, and C. Sagan. *Science.* Vol. 247, January 12, 1990, 166 - 176.

E) What alternative theories have been suggested to account for mass extinctions? A number of scientists suggest that there are frequent changes in the Earth's mantle that would result in massive volcanic activity.

Resources:
a) Volcanoes and extinctions: erupting of the impact idea? Stefi Weisburd. *Science News.* Vol. 127, 1984, 172.
b) Volcanoes and extinctions: Round two. Stefi Weisburd. *Science News.* Vol. 131, April 18, 1987, 248 - 250.
c) A volcanic eruption. Vincent Courtillot. *Scientific American.* October, 1990, 85 - 92.
d) A thermal filter to extinction. Roger Lewin. *Science.* January 27, 1984, Vol. 223, 383 - 385.

F) Are we now experiencing a mass extinction event? Determine the current rate of species extinctions. How does this compare to the rate of background extinctions in the past? the estimated rate for extinctions during a mass extinction event? What appear to be the causes of extinctions going on today?

Resources:

a) Extinction rates past and present. Norman Myers. *BioScience*. January. 1989, Vol. 39, 39 - 41.
b) Mass extinctions past and present. Warren D. Allmon. *Journal of Geological Education*. 1987, Vol. 35, 197 - 200.
c) The disintegrating web: The causes and consequences of extinction. G. Jon Roush. *Nature Conservancy Magazine*. November/December, 1989, 4 - 15.
d) Avoiding a mass extinction of species. Edward C. Wolf, In Lester R. Brown (Ed.). *State of the World*. 1988. Chapter 6, WorldWatch Institute.

Panel discussions

4) Each team should make a brief presentation on its topic. Questions from the panel and audience should be permitted. Following the panel discussion, each student should write a short paper in which the salient points of each presentation are synthesized.

Activity D: Could we prevent mass extinctions by meteorite impact?

As a conclusion for this activity you might want to conduct a discussion about possible efforts to prevent collisions of the Earth and meteorites. Use the following articles as a source of information:

a) How to prevent the extinctions. Kelly Tasker, *Discover*, May 1984, 30 - 32.
b) The Science of Doom. Sharon Begley, *Newsweek*, Nov. 23, 1992, 56 - 61.
c) Heads Up. *Time*, Nov. 9, 1992. 27.

Extensions:

1) You might encourage your students to read the following books:
Stephen Jay Gould, *Its a Wonderful Life*, published by W.W. Norton Company, New York, 1989. This is a discussion of the implications of the Burgess Shale fauna for our understanding of the nature of evolution. Entertaining and informative reading on the nature of science, scientific investigation and theory development.

Michael Critchton, *Jurassic Park*, New York: Alfred A. Knopf, 1990. The author weaves modern developments in genetic engineering, paleontology and chaos theory into a chilling tale which questions our reductionist, deterministic bent in science. The story evolves around the recreation of dinosaurs from DNA fragments found in fossils with the idea of creating the ultimate amusement park. As you might expect, things go terribly wrong.

2) Many science-fiction movies of the past concentrated on issues such as planets approaching Earth and colliding with it. From the research you have conducted, is such a situation possible? Is there anything that we could do to be prepared for this situation?

3) Paleontologists are scientists who study fossils and records of the past. They are involved with many different areas of industry, research and teaching. Select one industrial, research and teaching application of paleontology and write a one page report. Also discuss how the work of these scientists has impacted your life style.

4) Dinosaurs lived many millions of years ago, when the world was very different from its present appearance. You are able to take a quantum leap back into that time period and you return with photographs, illustrations and descriptions of this world. Once you have had time to collate your discoveries you present your findings to the general public and the media. Using the classroom as the press conference, present your findings.

Teacher Background Information:

Begley, S. 1992. "The Science of Doom." *Newsweek.* November 23. 1992. p. 56 - 61.
The author examines various objects floating in space and the possibility of a collision with Earth. She investigates the Comet Swift-Tuttle and the controversy whether or not it will impact the planet. The visible evidence of past collisions and how to prevent future collisions are documented. This is an informative article with superb photographs and illustrations.

Natural History Museum of Los Angeles County. 1987. *Dinosaurs Past and Present, Volumes I and II.* Seattle and London: University of Washington Press.
Includes spectacular art depicting our current understanding of how the dinosaurs lived and died.

Stanley, S. M. 1991. "Extinctions — Or, Which Way Did They Go?" *Earth.* Kalmbach Publishing Co.
This article discusses the different theories on the extinction of the dinosaurs. It also documents the rise of the dinosaurs through geologic time. Illustrations based on scientific information compose a picture of the world at this stage of the world's history.

References:

Sources of pictures for Activity B

Boucot, A. J. 1990. *Evolutionary Paleobiology of Behavior and Coevolution.* New York: Elsevier Science Publishers.

Donovan, S. 1989. *Mass Extinctions: Processes and Evidence.* New York: Columbia University Press.

Finsley, C. 1989. *A Field Guide to Fossils of Texas.* Austin: Texas Monthly Press.

Stein, S. 1986. *The Evolution Book.* New York: Workman Publishing.

Additional readings

Gore, R. 1993. "Dinosaurs." National Geographic. Vol. 183 (1) : 2 - 53.

Gore, R. 1989. "Extinctions." *National Geographic.* Vol. 175 (6) : 662 - 699.

Jax, D. 1991. "How long is long ago?" *Science Activities.* Vol. 28, 27 - 28.

Thulborn, T. 1990. *Dinosaur Tracks.* New York: Chapman and Hall.

Wallace, J. 1987. *The Rise and Fall of the Dinosaurs.* New York: Michael Friedman Publishing Group, Inc.
Includes modern art depicting the new understanding of the life style of the dinosaurs.

VIDEO:

Walt Disney Home Video. *Fantasia.* Buena Vista Home Video, Dept. CS, Burbank, CA 91521.

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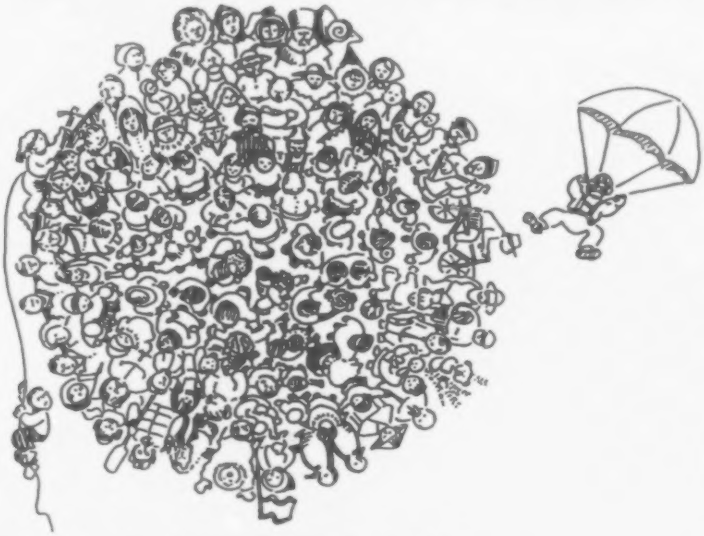
IT JUST KEEPS ON GROWING AND GROWING AND.....

When the astronauts left Earth's orbit and looked back they saw the 'blue planet.' They realized how beautiful it was, a bright shining planet in the blackness of space. Perhaps Astronaut William A. Anders of Apollo Mission 8 expressed it best when he said:

> "The Earth looked so tiny in the heavens that there were times...when I had trouble finding it. If you can imagine yourself in a darkened room with only one clearly visible object, a small blue-green sphere about the size of a Christmas-tree ornament, then you can begin to grasp what the Earth looks like from space. I think that all of us subconsciously think that the Earth is flat or at least almost infinite. Let me assure you that, rather than a massive giant, it should be thought of as the fragile Christmas-tree ball which we should handle with considerable care."
> **(Source: Nicks, *This Island Earth*, 14.)**

As the 21st century approaches, humans have many problems facing them — global warming, pollution, ozone depletion, disappearing biodiversity, etc. However, one of the more serious problems that faces everyone and threatens the planet is over-population — of humans. In 1990, an estimated **5.3 billion** people inhabited this planet. Every year another 95 million people are added to this number; by the end of the decade the world population will have increased by an extra **1 billion** people: a world with over **6 billion people** — a world that needs to feed, protect, educate, employ every individual. Is a planet like Earth capable of sustaining this number of people? By the year 2100 the world population will have almost doubled. Will Earth be any more capable then of sustaining this number of people?



(Illustration by L. Farr, The Ohio State University, 1993.)

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with the support of The Ohio State University.

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In this activity, the students will examine the growth of the human population and investigate the possible future consequences of continued population growth. The concepts studied in this activity include: *population; carrying capacity; finite resources; options for curbing human population; and impact of human population growth on the planet.*

Objectives: When this activity has been completed, each student should be able to:

1) see that limiting factors affect population growth (Activity A).
2) understand that most other species on the planet have some control on their population growth (Activity B).
3) describe how uncontrolled population growth affects other species in an ecosystem (Activity B).
4) examine the human population growth rate in different countries and the reasons why this rate fluctuates (Activity C).
5) investigate the impact that increasing human population will have on the world's resources (Activity C).

Earth Systems Understandings (ESUs): This activity concentrates on ESUs 2, 3 and 4, however, the following ESUs are covered in the Extensions — 1, 5 and 6. Refer to the Framework for ESE for a full description of each understanding.

Activity A: Will the population of organism 𝕏 ever stop growing?

For this activity, you will need to arrange the classroom furniture into five islands. By using an unnamed organism it allows the students to examine other options before deciding whether or not this organism represents humans.

Materials: peanuts, chocolate kisses, or other edible resource; rocks or other inedible resource; Population Cards I and II.

Procedure:

1) Before the students arrive, rearrange the furniture so that the tables and chairs are grouped in five 'islands.' These islands may differ in size, but should be large enough to accommodate up to 10 people. This game is designed for 25 people; if more students are present figures need to be adjusted. The game is divided into two ten minute sections — the goal of the first section of the game is to show a balanced population growth. The goal of the second section is to illustrate an uncontrolled population growth.

2) When the students arrive, inform them that you will begin today's class with a game. Do not tell them the name of the game, just that it concerns organism 𝕏.

3) Select 11 students that are assigned in the following way to the islands.

ISLAND 1 — 2 STUDENTS.
ISLAND 2 — 3 STUDENTS.
ISLAND 3 — 2 STUDENTS.
ISLAND 4 — 4 STUDENTS.
ISLAND 5 — 0 STUDENTS.

4) The remainder of the students represent a general pool of more 𝕏's that will be utilized throughout the game.

5) Each island receives different amounts of resources.

ISLAND 1 — 4 PEANUTS/10 ROCKS.
ISLAND 2 — 7 PEANUTS/ 8 ROCKS.
ISLAND 3 — 2 PEANUTS/ 2 ROCKS.
ISLAND 4 — 10 PEANUTS/15 ROCKS.
ISLAND 5 — 8 PEANUTS/15 ROCKS.

The peanuts represent the edible resources (food, water) in the area, while the rocks constitute the non-edible resources (soil, space, minerals, air, etc.).

6) You inform the students of an event from Population Cards I. (Produce multiple copies of the population cards.) The cards cover events such as birth of new organisms; death of organisms; migration; starvation caused by drought; etc. Randomly select events from the birth section first, so that the population increases. When an organism is born, that new organism is selected by the teacher from the pool of students outside the islands. Alternatively, if an organism dies, the teacher selects that dead 'organism' to join the pool of students. Then choose a disaster or other event for the population. The selection and sequence of events from the cards is decided by the teacher for each island. Use cards from pages 169 and 170.

7) Allow the students to eat the resources, but they must keep the waste on the island. Remember, however, that as the population increases, resources may increase initially but will eventually decrease.

8) After playing the game for almost ten minutes, ask the students if they could suggest any organism — plant or animal — that would fall under the category of organism 𝕏?

[Some students may answer humans, but continue playing the game.]

What factors are limiting the growth of this population?

[Natural events such as the disasters; food resources, etc.]

What is happening to the waste from the resources?

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[The waste is accumulating; some of it may be degraded.]

9) At certain stages in the game, the teacher can increase the number of edible resources on each island.

10) After 10 minutes, use Population Cards II for Round 2 (pages 171/172). Produce multiple copies of the cards. Because of technological advances, fewer organisms die in this section of the game. Randomly select events from the cards that will allow population growth to increase. The goal of the second part of this activity is to have all or most of the students on the islands by the end of the game. As the population of the organism increases, resources are utilized and decrease. For example, as another 𝕏 is added to the population, a segment of a resource is lost to the population. Most of the resources, edible and inedible, should be depleted towards the end of the game.

11) At the point when all the students are on the islands, or another ten minutes have elapsed, ask them the same question again. Could they suggest any organism — plant or animal — that would fall under the category of organism 𝕏? The answer this time should be humans.

12) Discuss with the students what has happened on the five islands. Where have the food and the other resources gone? How quickly did the food and other resources disappear? How did the non-edibles disappear?

What happened to the limiting factors? Are humans in this position yet?

[Answers will vary.]

The following activity sheets can be handed to the students.

Activity B: Oh deer!!!!!! Why are there so many of us?

One animal that has flourished with urbanization and habitat management has been the white-tailed deer (*Odocoileus virginianus*). Nationally, the population of white-tailed deer has dramatically increased from 500,000 a century ago to an estimated 25 million individuals. The deer population is now as large as when Europeans first colonized the U.S. This phenomenal increase in population has many associated problems. Of the 200 people that were killed nationally in animal-related accidents in 1991, over 130 were killed in deer/auto collisions.

Large deer populations also create a major impact on their own habitat and adjoining agricultural areas. Each day, a deer consumes five pounds of browse from among 600 species of plants including corn, wheat and wild plants. Annual damage to agricultural crops is tremendous, exceeding $36 million in many states. Browse lines to a height of 6 feet, as high as deer can reach, are seen on many trees in parks and recreation areas. The biodiversity of habitats is seriously disrupted, and recovery may take many years. The risk of Lyme Disease also increases, as there is a greater possibility of more deer-borne ticks spreading the disease.

The situation in Ohio, similar to many of the other eastern and mid-western states, has reached a critical level. Ohio's deer population doubled in the last decade, reaching 450,000 in 1992, and it is projected to increase to over 500,000 in 1993. A Division of Wildlife spokesperson for the Ohio Department of Natural Resources stated that part of the problem is that deer herds have grown unchecked in areas such as municipal and county parks, where hunting is prohibited.

Scientific data for Sharon Woods Metro Park, a 1.6 km square park in the Columbus area, show a decline in plant diversity from 350 plant species in 1900 to 40 in 1992. Vertebrate diversity also declined in the same time period from 25 to seven species. Could deer cause the decline of other species in the habitat? Or could the one million people or more who visit the park annually be responsible for this decline in species diversity?

Materials: graph sheets or graph computer software; Tables 1 and 2; calculator.

Procedure:
Examine the data in Tables 1 and 2, and investigate the following points.

1. Has the deer population affected the diversity of plant and vertebrate species in the park? When did this impact begin to manifest itself?

2. Graph the increase in the deer population, and the decrease in plant and vertebrate diversity. Calculate the percent increase in population for the deer for each decade. Calculate the percent decrease for the diversity of each group over the same time periods. What information does this give you? Is any pattern visible from these figures?

3. At the current rate of population growth, calculate and graph the size of the Sharon Woods deer herd in the year 2000, 2020 and 2050.

4. Female deer reach breeding maturity at 6 - 8 months. Beginning with 4 individual deer, 2 males and 2 females, calculate the maximum number of offspring produced in a seven year period. Assume that the offspring of the four deer are divided into a 50:50 ratio, male-female. If these are included in the calculation as breeding animals as the herd matures, what size herd could exist at the end of the seven year period? Predation and disease are not considered to have an impact in this calculation.

5. Calculate the fertility of white-tailed deer by creating a fertility graph from the information in Table 2. Graph your results for each year from 1985 to 1992.

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AGE	AVERAGE WEIGHT (lbs)	REPRODUCTIVE RATE/YEAR
1	100	1
2	160	2
3	200	2
4	220	2
5	235	3
6	260	3
7	280	3
8	300	3

Table 1. - Chart shows increasing weight and reproductive rates for white tailed deer in Ohio. (Source: Ohio Department of Natural Resources, 1992.)

YEAR	NUMBER OF DEER	PLANT DIVERSITY NO. OF SPECIES	VERTEBRATE DIVERSITY NO. OF SPECIES
1940	—	500	25
1950	—	500	25
1960	3	500	25
1970	30	500	25
1980	50	500	25
1982	75	440	22
1984	120	360	21
1986	170	220	17
1988	190	100	12
1990	220	45	8
1992	350	40	7

Table 2. - Chart illustrating changes in deer population, plant and vertebrate diversity for Sharon Woods Metro Park in Columbus, Ohio. (Source: Ohio Department of Natural Resources, 1992.)

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Using the information from the Sharon Woods data, and the general trend in a growing deer population nationally, answer the following questions.

6. Why did the deer population increase to its present 1992 level?

7. What ecological conditions allowed this explosive growth to occur?

8. What are the conditions or limiting factors affecting the deer population?

9. What size herd do you think a park this size can support? What deer population can the nation support? What is the carrying capacity? Are other plant and animal species impacted by this herd size? Support your answer with evidence.

10. Metro parks are controlled, managed environments. Using Sharon Woods as an example, how could poor planning have contributed to the present deer problem?

11. What impact do you think the high number of visitors to a metro park would have on a deer herd?

Use the two graphs on loss of diversity that you created in question 2 to answer the following questions.

a) How has the loss of plant diversity influenced the ecosystem of the park?

b) Certain species of plants remain uneaten by the deer. Why is this? What impact could this have on the park's ecosystem?

c) Why has a loss in animal diversity occurred? Will it continue?

d) What could happen to the diversity of plants and animals if the deer population is reduced?

e) Sharon Woods Metro Park is surrounded by residential areas and highways on all sides. What influence do you think this would have on human/deer interactions?

f) Why would deer leave the park area?

g) If the deer population continues to increase within the park, what will eventually occur?

h) At what population might this ecological collapse occur? Why? Why hasn't this occurred already? Will the ecosystem be altered in any way, following this collapse?

i) A decision has been made by the park board to cull the deer. Approximately 80% of the deer herd will be harvested. Is this decision justified? Why? Should it have been done sooner?

Activity C: Will climate change influence the carrying capacity of Earth?

According to Zero Population Growth, in the 6 seconds it takes you to read this sentence, 24 people will be added to the Earth's population. Every hour the population increases by 11,000; by the day's end that figure reaches 260,000. It took four million years for humanity to reach the 2 billion mark, but only 30 years to add a third billion. The annual increase is 95 million people. No wonder they call it the human race!

Earth is a dynamic place, constantly changing. All life-supporting systems of the planet are interlinked and all processes are in flux. Most scientists agree that climate is changing. Present climatic conditions are quite different from those of 10,000 years ago. However, the big debate is over the magnitude and type of change that will occur. A growing human population needs to be cognizant of this change and the challenges posed by such alterations. Scientists have predicted that many areas in east and west Africa, Asia and some areas of the U.S. will experience increased precipitation levels in the next 100 years. Associated with this is a temperature increase ranging from 1.5 - 4.5°C. While this may seem small, a change of 2°C would create a planetary atmosphere warmer than at any time in the past 100,000 years.

Changes in temperature and precipitation will undoubtedly influence the hydrologic cycle. Sea level is predicted to rise and will flood many coastal regions. Many countries are preparing for the predicted rise. The Netherlands, with 2/3 of its land at sea level, has always had protective dikes around the coastline. After a severe storm in 1953 which killed 2,000 people and caused millions of dollars damage, dikes were raised by 2 - 3 meters. This cost $10 billion, a figure that includes continual maintenance. Such investment absorbs one half to one percent of the country's annual Gross National Product (GNP). Developed countries, such as the Netherlands and the U.S., may be able to afford such dike projects, but what of the developing countries? In 1980 over 600 million people inhabited the world's coastal regions. This number has been projected to increase to almost 1 billion by the year 2000. In addition, 50% of this increase will be concentrated along the shores of Asia.

Consider some of the following predictions: an increase of 1°C would cause a sea level rise of approximately 330 cm (1 ft.), a rise that is 3 - 6 times faster than experienced over the last 100 years. A sea level rise of 1 meter would eliminate 3% of Earth's land area. (For additional information on temperature increase and associated sea level rise, check the possible consequences of the Global Climate Game.)

In this activity, you will predict the possible impacts of climate change on the demographics of various countries.

Materials: copy of Table 3; world map; calculator.

COUNTRY	LENGTH OF COASTLINE (KILOMETERS)	POPULATION IN COASTAL AREAS (THOUSANDS)	
		1980	2000
EGYPT	2,450	4,246	8,020
ETHOPIA	1,094	760	1,909
LIBERIA	579	465	1,195
MAURITANIA	754	238	1,177
SOMALIA	3,025	1,186	3,308
SUDAN	853	356	1,193
CANADA	90,908	3,066	3,852
UNITED STATES	19,924	60,324	74,305
BANGLADESH	580	1,809	5,503
CHINA	14,500	38,936	66,510
INDIA	12,700	37,317	78,255
INDONESIA	54,716	29,166	58,303
MALDIVES	644	N/A	N/A
MYANMAR (BURMA)	3,060	3,923	7,695
IRELAND	1,448	1,766	2,469
NETHERLANDS	451	7,764	9,032
PORTUGAL	1,693	2,352	3,499
UNITED KINGDOM	12,429	26,765	27,790

Table 3. - Length of coastline and densities of coastal populations in selected countries from Africa, North America, Asia and Europe. (From: *World Resources 1992-93* by Allen L. Hammond (Editor-in-Chief). Copyright © 1992 by the World Resources Institute. Reprinted by permission of Oxford University Press, Inc.)

Procedure:

1) Locate the countries from Table 3 on a world map. Select one country and answer the following questions.

2) Discuss the implications of sea level rise for the country under the following topics: population migration; social impacts; developed or developing status and ability to respond to this situation; agricultural losses; recreational areas; disturbance of groundwater process, and financial repercussions.

3) Predictions for the year 2050 suggest that the Maldives would be totally submerged and the Indonesian islands, which comprise 40% of the world's coastline, would face a national disaster. What international repercussions could you foresee from this situation?

4) One Dutch scientist has suggested that instead of investing another $10 billion to combat additional sea level rise that this money should be used to regulate the

causes of this process, namely greenhouse gases. Do you agree with this statement? Give reasons for your answer.

5) The growth of human population has many additional impacts on the environment and resources. List five environmental issues that you consider important. What impact does human population and its growth rate have on these issues? Could a decrease in growth help the present situation? Why? Why not? Will human impact continue in these issues?

6) In Activity B, it was seen that the deer population kept increasing until the population reached a critical level. At that point, it was decided to cull the herd because it had a serious impact on the other species in the ecosystem. Humans killed most of the deer's predators as civilization encroached on the original habitat. So the decision to cull the herd and control its size was a human one. Is the human species at this critical level now? Have we passed it? When will we reach it? As the human population continues to grow, what impacts are created on the environment? What are the factors that could "cull" the human population?

7) In the past, humans had to contend with limiting factors. Do we still have these limiting factors? Are these as severe as they were originally? Has technology helped us overcome these limiting factors in some way?

8) Produce a concept map that features humans and the different implications of our uncontrolled growth.

Extensions:

1) Listen to Dan Fogelberg's song 'Gone Too Far' on his 1984 album *Windows and Walls*. In this, he sings that there are "6 billion people, where there's room for three" on the planet and he wonders if we are "wishing on a dying star." After listening to his song and from the information you have learned in this activity, do you think this is the case? Is the human race about to destroy this planet, the only one known to support life as we know it? What do you think? Give reasons to support your answers.

Read "If the world were a village of 1,000 people....", located before the references. Describe your feelings toward this fact sheet. Is it alarming or just interesting? What if you were a person in this community? How would you feel about your world? Would you enjoy living in it?

2) Earth has been evolving for billions of years, creating an environment that is unique in the solar system. Yet in the short time that humans have appeared on the planet, they have impacted the environment enormously, creating incredible alterations in ecosystems. Try to describe the type of planet you will inhabit in the year 2050. How different will it be? How many more people will be in the U.S.?, in the world? In what way will your local environment/community be different?

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3) If the world does become overcrowded and resources over-utilized, what options does the human species have? Will the construction of space stations or the colonization of other planets help us to solve our problems? How feasible are these options? Do we really have any option other than controlling the growth of our population?

4) Examine a country with a large growing population, such as China or India. How have the governments in these countries tried to curb their growth? Do you agree with these policies? Does any government have the right to impose laws that restrict the number of children in the family? Do the 'needs of the many outweigh the needs of the few or one'?

5) Examine the data from the 'Population and Human Development' section of *World Resources 1992-93* or the most current year. Select one of the countries used in Activity C and examine how other factors such as mortality, nutrition and access to safe drinking water impact the growth rate and population in the selected country.

6) Select a population issue in your local area, like the Sharon Woods deer management issue, and prepare a report for your class on the different groups involved and their reasons for agreeing or disagreeing with the proposed management policy. The students should then select various roles within these groups and hold a town meeting on the issue. At the end of the role-playing, each student should construct a flow chart or concept map on the issue and the decisions involved.

7) Select one day of the week and do a personal inventory for that day. From the moment you arise in the morning to when you go to sleep at night, document every resource you use: How much water you use, how many pop cans you crush and recycle (if you do recycle), how much paper you write on, how you travel to school and so on. List all the resources on a page and how much you use in various columns. The following day, take this to school and compare it to the other students. Produce a chart illustrating how many resources each individual in the class used and the total for the whole class. Now multiply this amount by the numbers of classes in your school, the number of schools in your district, county, state, country. Discuss what you have discovered about humans and resource utilization. How does this resource utilization relate to climate change? How does your present lifestyle contribute to enhanced climate change? Are you willing to alter your lifestyle to reduce its impact on climate change? How?

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Population Cards I

Birth

Conditions remain constant —

No population growth.

No population growth.

Conditions improve —

An organism is born.

An organism is born.

An organism is born.

An organism is born.

An organism is born.

Conditions improve —

Two organisms are born.

Two organisms are born.

Two organisms are born.

Two organisms are born.

Two organisms are born.

Conditions improve —

Three organisms are born.

Three organisms are born.

Three organisms are born.

Three organisms are born.

Death

Organisms die of old age/inquiry

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

Two organisms die.

Two organisms die.

Two organisms die.

Organisms are killed.

Two organisms are killed

Two organisms are killed.

Three organisms are killed.

Three organisms are killed.

Two organisms are killed.

Two organisms are killed.

One organism is killed.

One organism is killed.

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DISASTERS

Flood destroys home. Two organisms die, food reserves wiped out .
LOSE 2 PEANUTS.

Earthquake kills 4 organisms. Destroys food reserves and resources.
LOSE 3 PEANUTS AND 4 ROCKS.

Tornado kills four organisms. Destroys food reserves and resources.
LOSE 4 PEANUTS AND 4 ROCKS.

Floods destroy home. No deaths.
LOSE 5 PEANUTS AND 2 ROCKS.

Drought causes widespread famine.
HALF OF THE POPULATION DIE AND HALF REMAINING FOOD RESOURCES ARE LOST.

Flood destroys home. Two organisms die, some food reserves lost .
LOSE 2 PEANUTS.

Fire devastates area. One organism dies.
LOSE 4 PEANUTS AND 6 ROCKS.

Tornado kills four organisms. Destroys food reserves and resources.
LOSE 4 PEANUTS AND 4 ROCKS.

Flood destroys home. Two organisms die, some food reserves lost .
LOSE 2 PEANUTS.

Drought causes widespread famine.
HALF OF THE POPULATION DIE AND **HALF REMAINING FOOD RESOURCES ARE LOST.**

Tornado kills four organisms. Destroys food reserves and resources.
LOSE 4 PEANUTS AND 4 ROCKS.

MIGRATION

Two organisms migrate and get killed in the process.

Three organisms migrate and get killed in the process.

Three organisms migrate, one returns to colony, the other dies.

Four organisms migrate but stay in island.

Two organisms migrate within island.

Two organisms migrate within island.

Three organisms migrate within island.

Three organisms migrate within island.

Three organisms migrate within island, but two get killed.

Three organisms migrate within island, but two get killed.

Three organisms migrate within island, but one gets killed.

Three organisms migrate within island, but two get killed.

Three organisms migrate within island, but one gets killed.

Three organisms migrate within island, but one gets killed.

Three organisms migrate within island, but all three get killed.

Three organisms migrate within island, but two get killed.

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Population Cards II

Technological Advances

Birth

Living conditions improve —

The population increases by two.

The population increases by two.

The population increases by two.

The population increases by two.

Living conditions improve —

The population increases by three.

The population increases by three.

The population increases by three.

The population increases by three.

The population increases by three.

The population increases by three.

Living conditions improve —

The population increases by four.

The population increases by four.

The population increases by four.

The population increases by five.

The population increases by five.

The population increases by five.

Death

Organisms die of old age/inquiry

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

One organism dies.

Two organisms die.

Two organisms die.

Two organisms die.

Organisms are killed in accidents.

One organism is killed

Two organisms are killed.

Three organisms are killed.

Three organisms are killed.

One organism is killed.

One organism is killed.

One organism is killed.

One organism is killed.

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DISASTERS

Flood destroys home. One organism dies, food reserves wiped out . But aid brings in food. **LOSE 1 PEANUT.**

Earthquake kills four organisms. Destroys food reserves and resources. But aid brings in food. **LOSE 2 PEANUTS AND 4 ROCKS.**

Tornado kills four organisms. Destroys food reserves and resources. But aid brings in food. **LOSE 4 PEANUTS AND 4 ROCKS.**

Floods destroy home. No deaths. But aid brings in food. **LOSE 3 PEANUTS AND 2 ROCKS.**

Drought causes widespread famine. **HALF OF THE POPULATION DIE AND HALF REMAINING FOOD RESOURCES ARE LOST.** But aid brings in food.

Flood destroys home. Two organisms die, some food reserves lost. But aid brings in food. **LOSE 1 PEANUT.**

Fire devastates area. One organism dies. **LOSE 4 PEANUTS AND 6 ROCKS.** But aid brings in food.

Tornado kills four organisms. Destroys food reserves and resources. **LOSE 4 PEANUTS AND 4 ROCKS.**

Flood destroys home. Two organisms die, some food reserves lost . **LOSE 2 PEANUTS.**

Tornado kills four organisms. Destroys food reserves and resources. But aid brings in food. **LOSE 4 PEANUTS AND 4 ROCKS.**

MIGRATION

Two organisms migrate and get killed in the process.

Two organisms migrate and get killed in the process.

Two organisms migration, one returns to colony, the other dies.

Four organisms migrate out of island.

Two organisms migrate out of island.

Two organisms migrate out of island.

Three organisms migrate out of island.

Three organisms migrate out of island.

Three organisms migrate out of island, but two get killed.

Three organisms migrate within island, but one gets killed.

Three organisms migrate within island, but one gets killed.

Three organisms migrate within island, but two get killed.

Three organisms migrate out of island, but one gets killed.

Three organisms migrate within island, but one gets killed.

Three organisms migrate out island.

Three organisms migrate within island.

Three organisms migrate within island.

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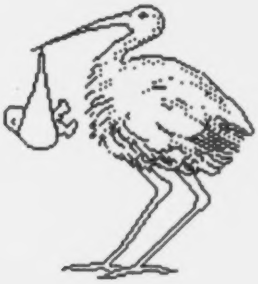
If the world were a village of 1,000 people..........

- If the world were a village of 1,000 people, it would include: 584 Asians, 124 Africans, 95 East and West Europeans, 84 Latin Americans, 52 North Americans, 6 Australians and New Zealanders, and 55 people from the territories of the old USSR.

- One-third (330) of the 1,000 people in the world village are children and only 60 are over the age of 65. Half of the children are immunized against preventable infectious diseases such as polio.

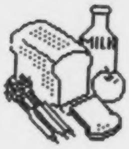
- Just under half of the married women in the village have access to and use modern contraceptives.

- The first year 28 babies are born. That year 10 people die, 3 of them for lack of food, 1 from cancer. Two of the deaths are of babies born within the year. One person of the 1,000 is infected with HIV virus; that person most likely has not yet developed a full-blown case of AIDS.

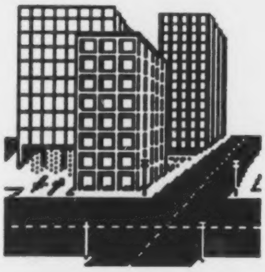


- With the 28 births and the 10 deaths the population of the village in the second year is 1,018.

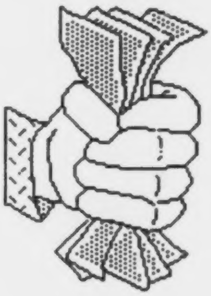
- The village has 6 acres of land per person, totaling 6,000 acres. Of the 6,000 acres: 700 acres are cropland, 1,400 acres pasture, 1,900 acres woodland, 2,000 acres desert, tundra, pavement and other wasteland.



- The woodland is declining rapidly, while the wasteland in rapidly increasing. The other land categories are roughly stable.



- In this thousand-person community, 200 people receive 75 percent of the income; another 200 receive only 2 percent of the income.



- Only 70 people of the 1,000 own an automobile (although some of the 70 own more than one automobile).

- Of the 670 adults in the village, half are illiterate.

- Of the 1,000 people, 5 are soldiers, 7 are teachers, 1 is a doctor, and 3 are refugees driven from home by war or drought.

(Source: Zero Population Growth, 1992.)

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Teacher Background Information:

Berreby, D. 1991. "The Numbers Game." *Environment 91/92.* Guilford, CT.: The Dushkin Publishing Group.
This article is a superb discussion of two sides of the population argument. One, espoused by Paul Ehrlich, forecasts great catastrophes and millions of starving people. On the other hand, Julian Simon, an economist, states that the statistics may not be right, because the planet is now sustaining far more people than predicted thirty years ago. An interesting and thought-provoking discussion ensues.

Mathews, J. T. 1991. "Rescue Plan for Africa." *Environment 91/92.* Guilford, CT.: The Dushkin Publishing Group.
This article documents the current status of this continent and what the future holds for it. It examines such areas as motherhood, food, water, agricultural practices, etc. As a case study of a developing region it is excellent.

The World Resources Institute. *World Resources 1992-93 A Guide to the Global Environment.* New York: Oxford University Press.
This book deals with various aspects of the planet, gives specific data on each aspect. Each section covers a different topic from 'Dimensions of Sustainable Development' to 'Atmosphere and Climate'. Each section also includes case studies on issues within that topic. An excellent reference for students and teachers. New volumes are produced every two years.

References:

Allen, J. L. 1991. *Environment 92/93.* Guilford, CT.: The Dushkin Publishing Group.
This is an excellent annual publication with a great variety of articles concerning different environmental topics. Each publication is divided into the same six units dealing with topics such as energy and population. However, the articles within these units differ from year to year.

Brown, L. R., Durning, A., Flavin, C., French, H., Jacobson, J., Lenssen, N., Lowe, M., Postel, S., Renner, M., Ryan, J., Starke, L., Young, J. 1991. *State of the World. A Worldwatch Institute Report on Progress Toward a Sustainable Society.* New York: W. W. Norton & Company.

Cline, W. R. 1992. "Global Warming: The Economic Stakes." *Policy Analyses in International Economics.* No. 36. Washington D.C.: Institute for International Economics.

Crews, K. A., and Cancellier, P. (Editors). 1991. *CONNECTIONS - Linking Population and the Environment. Teacher's Guide and Student's Guide.* Washington D.C. 2009-5728: Population Reference Bureau, Inc., 1875 Connecticut Avenue, N.W. Suite 520.

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Nicks, O. W. (Ed.) 1970. *This Island Earth.* Washington D.C.: Scientific and Technical Information Division, Office of Technology Utilization, National Aeronautics and Space Administration. NASA SP-250.

Wasserman, P. and Doyle, A. 1991. *EARTH Matters - studies for our global future.* Washington D.C. 20036: Zero Population Growth, Inc. 1400 16th St., NW, Suite 320.

Zero Population Growth. 1992. *If the world were a village of 1,000 people...* Washington D.C. 20036: Zero Population Growth, Inc. 1400 16th St., NW, Suite 320.

VIDEO:

WGBH Foundation. 1990. "Only One Atmosphere." *Race to Save the Planet.* This program is an excellent summary of some of the possible consequences of changes in the atmosphere. Sea level rise is examined about 25 minutes into the program, however, this program should be viewed fully as it presents an overview of the problems that we may face in the coming decades.

Zero Population Growth Inc. 1991. *Population Growth.* Washington D.C. 20036: 1400 16th St., NW, Suite 320.
This is an excellent five minute presentation which illustrates the exploding human population. At the beginning, the screen is filled with a globe which unfolds to become a world map. The narrator explains that human population growth will be shown on the map through the use of dots. Each dot represents one million people. This video does not pass any moral judgments or solutions. It just states that the world is finite and records the growth in human population since 1 A.D.

TROPICAL DEFORESTATION: CAUSES, EFFECTS, AND IMPLICATIONS

Global environmental change creates numerous aspects of simultaneous or rapidly successive alterations in the hydrosphere, lithosphere, atmosphere, biosphere and cryosphere. In fact, if any one aspect is considered, such as sea level rise, it is impossible to consider that change in isolation from others in the other Earth subsystems -- coastal land use, wetlands protection, glacial melting, and the greenhouse effect.

Likewise, when we look at biomass burning, such as in the Brazilian Amazon, the extent of the burning is such that it affects all parts of the local ecology and also creates global impacts.

Tropical rainforests cover 30 million square kilometers, over 10% of the Earth's land surface (Figure 1). They originally covered at least twice that area. Tropical rainforests receive 4 to 8 meters of rain a year. This produces heavy vegetation which deflects the rainfall so that water reaches the forest floor by rolling down branches and trunks or as a fine spray. Tropical rainforests have no distinct seasonality — no dry or cold season of slower growth.

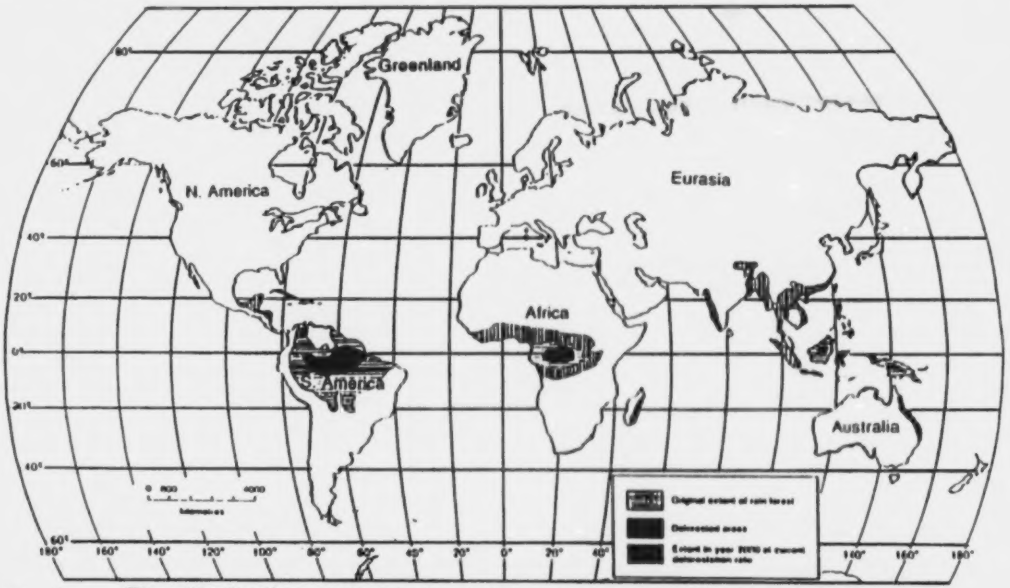
Greenland
N. America
Eurasia
Africa
S. America
Australia
80°
60°
40°
20°
0°
20°
40°
60°
180°
160°
140°
120°
100°
80°
60°
40°
20°
0°
20°
40°
140°
160°
180°
Original extent of rain forest
Deforested areas
Extent in year 2000 at current deforestation rate

Figure 1. - The distribution of tropical rainforests and the extent of present and potential future deforestation. (Source: Adapted from Mannion, *Global Environmental Change: A Natural and Cultural Environmental History*, 1991.)

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with the support of The Ohio State University.

Tropical rainforests are exceptionally important because of their geographic location and their interaction with the environment and climate. Because of their geographic location, they receive higher intensities of solar radiation than any other places on the Earth. Tropical rainforests are the Earth's oldest continuous ecosystem. Unfortunately tropical deforestation is the most significant current land coverage change on the Earth. Fifty-five percent of the Earth's 5.2 billion people live in the tropics. Humans have already destroyed 50% of the tropical rainforests. Approximately 100,000 square kilometers are eliminated every year. In some countries deforestation has been especially severe. If deforestation continues at its present rate in the Amazon the tropical rainforests will be completely eliminated in 100 years. Even worse, the destruction of tropical rainforests is irreversible. The deforestation process alters the hydrologic cycle, creates soil erosion and soil infertility, and disrupts the complex interaction between plants and animals. Replanting tropical rainforests, the way we replant in tree farms for timber harvest, would not work.

The concepts studied in these activities include: *tropical deforestation; biodiversity; biomass burning and the results of deforestation.*

Objectives: When the students have completed this activity, they will be able to:

1) locate on a world map the countries with major tropical rainforests (Activity A).
2) describe the population size, food resources, and financial condition of countries with major tropical rainforests (Activity A).
3) describe the extent of the Earth's tropical land mass that has been deforested in recent years (Activity B).
4) describe in detail one possible serious global consequence of deforestation (Activity C).
5) summarize the possible effects and implications of deforestation (Activity C).
6) evaluate which consequences of deforestation will have the most significant impact on global conditions (Activity C).
7) develop a conceptual scheme that demonstrates relationships between biomass burning and other global environmental changes (Evaluation).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3 and 4. However, the following ESUs are covered in the Extensions - 1, 5 and 7. Refer to the Framework for ESE for a detailed description of these understandings.

Activity A: Where and why does tropical deforestation occur?

The increased rate of deforestation in the past 100 years can be attributed to several factors. First, the rapid decline in tropical forests is frequently caused by the demand for food. Tropical forests are largely found in developing countries where population growth is rapid and pressure on the land for food production is high. As a result many of these countries practice "slash and burn" techniques to clear forests and open the area for agricultural production. A second cause for deforestation is the demand from developed countries for the resources found in tropical forests. These products include lumber, rubber, and the active ingredients for many pharmaceuticals.

In the U.S., 50 % of all prescriptions dispensed contain substances of natural origin derived from plants (Table 1). Every year the U.S. imports millions of dollars of tropical plants for use in the manufacture of pharmaceuticals. Finally, many of these developing countries must exploit their forests in order to pay off their debt to developed countries. This debt contributes to the destabilization of developing countries by encouraging the rapid and unplanned conversion of their forests into cash.

In this activity students will first locate the countries with major tropical rainforests and then investigate how these countries use their rainforests as a resource for either food, financial income or both.

MEDICINAL PLANT	SPECIES	HABITAT	ACTIVE INGREDIENT(S)	MEDICINAL USES
BENZOIN TREE	Strax benzoin	tropical Asia	benzoin	treatment of laryngtis; heals small cuts and chapped or blistered skin
BRAZILIAN IPECAC	Cephaelis ipecacuanha	Brazil	isoquinoline alkaloids, including cephaeline	treatment of dysentry; induces vomiting in cases of poisoning
COCA	Erthroxylum coca	South America	cocaine (alkaloid)	sedative; treatment for asthma; local anesthetic; relief of hemorrhoids and neuralgia
JABORANDI TREE	Pilocarpus jaborandi	Brazil	pilocarpine (alkaloid)	treatment of glaucoma; diuretic; sweat inducement; treatment of rheumatism and baldness
MEXICAN YAM	Dioscorea composita	Mexico	steroids (diosgenin); incl. saponins, cortisone	contraceptive pills; treatment of arthritis, skin diseases, Addison's disease
PAREIA	Chondrodendron tomentosum	South America	D-tubocurarine	muscle relaxant during surgery; aids therapy for polio and cerebral palsy; treatment of epileptic seizures
PERUVIAN BALSAM	Myroxyton balsamum	Central America, southern Mexico	benozoic acid	heals cuts and wounds; treatment of gonorrhea, rheumatism, asthma, bed sores, ulcerations, diaper rash, and hemorrhoids
QUININE TREE OR PERUVIAN BARK	Cinchona calisaya or Cinchona pubescens	South America	quinine	cure for fevers and malaria, regulated arrhythmical heartbeat
RAUWOLFIA	Rauwolfia serpentina	tropical S. America, Asia, Africa	resperine (alkaloid)	treatment of leukamia, Hodgkin's disease
TURMERIC	Curcuma longa	tropical areas of Far East	curcumin	treatment of blood diseases and eye infections; aid to digestion

Table 1. - Tropical plants and their medicinal uses. (Source: Oldfield, *The Value of Preserving Genetic Resources*, 1984.)

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Materials: blank 8 1/2" X 11" world map (use map on page 145); colored pencils, (green); world atlas; library resources or computer data bases for information about tropical countries (check reference list at end of activities for help if necessary).

Procedure:

1) Pass out a blank map of the world and have students draw in and shade green the location of major tropical rainforests using Figure 1 and Table 1.

> [When completed point out to the students the latitudinal location of the rainforest and the climatic conditions which produce it.]

2) Divide the class into groups of 2. Assign each pair a country from Table 2. Each student in the group should prepare answers for the following set of questions.

A) What is the present population of the country? What percentage of the country is covered by rainforests? What are its present sources for food? What is the current financial condition of the country? What kind of jobs do individuals have in the country?

> [An up to date Almanac and World Atlas or a set of encyclopedias would be a good place to start.]

B) Does the country practice a "slash and burn" policy? Does the country actively use rainforests to produce lumber, rubber, and pharmaceuticals? Is the country developing any type of policy that you can determine which tries to preserve its rainforests? Is the U.S. a help or hindrance to the preservation of the rainforests in this country?

Country	**Area of rainforests (hectares)**	**Population**
Brazil	357,180,000	153,300,000
Indonesia	113,895,000	181,400,000
Zaire	105,750,000	37,800,000
Peru	69,680,000	22,000,000
India	51,841,000	859,200,000
Colombia	46,400,000	33,600,000
Mexico	46,250,000	85,700,000
Bolivia	44,010,000	7,500,000
Papua New Guinea	34,230,000	3,900,000
Burma	31,941,000	42,100,000
Venezuela	31,870,000	20,100,000
Congo	21,340,000	2,300,000
Malaysia	20,995,000	18,300,000

Table 2. - Countries of the world containing large rainforests and their population in 1990. (Source: Population Reference Bureau Inc., *World Population Data Sheet*, 1991.)

3) Each group should make a poster presentation to the class about its country including a map locating the country, the exact location of the rainforests in that country, a chart showing the financial status of that country, and what efforts are being made by the country to preserve its rainforests. The human population and its growth also has an important impact on deforestation. This should be examined in your discussion. Groups may display posters and summarize information in two minutes.

Evaluation:

At the end of all the poster presentations each student should write a summary paper which reviews all the possible causes for deforestation and some possible solutions to help preserve the rainforests on a global scale.

Activity B: How big is the problem of biomass burning?

According to estimates by the U.N. Food and Agriculture Organization, dense tropical forests throughout the world have been disappearing at a rate of over 40 million acres a year, an area the size of the state of Washington, for 1981-1990. This is 83% faster than the rate estimated for the period of 1976-1980. Some geographic areas experiencing rapid deforestation include those listed in Table 3. A common method of deforestation is slash and burn. This technique involves clearing areas of forest for agriculture, by cutting down the trees and then burning any remaining vegetation. The nutrients stored in the multi-layered canopy mix with the barren topsoil, where they are quickly washed away. Once the section of land becomes non-productive, the farmer moves on to another area.

Regions/Subregions	Number of Countries Studied	Total Land Area	Forest Area,1980	Forest Area,1990	Area Deforested Annually 1981-90	Annual Rate of Change 1981-90 (percent)
Total	87	4,815,700	1,884,100	1,714,800	16,900	-0.9
Latin America	32	1,675,700	923,000	839,900	8,300	-0.9
Central America and Mexico	7	245,300	77,000	63,500	1,400	-1.8
Caribbean Subregion	18	69,500	48,800	47,100	200	-0.4
Tropical South America	7	1,360,800	797,100	729,300	6,800	-0.8
Asia	15	896,600	310,800	274,900	3,600	-1.2
South Asia	6	445,600	70,600	66,200	400	-0.6
Continental Souteast Asia	5	192,900	83,200	69,700	1,300	-1.6
Insular Southeast Asia	4	258,100	157,000	138,900	1,800	-1.2
Africa	40	2,243,400	650,300	600,100	5,000	-0.8
West Sahelian Africa	8	528,000	41,900	38,000	400	-0.9
East Sahelian Africa	6	489,600	92,300	85,300	700	-0.8
West Africa	8	203,200	55,200	43,400	1,200	-2.1
Central Africa	7	406,400	230,100	215,400	1,500	-0.6
Tropical Southern Africa	10	557,900	217,700	206,300	1,100	-0.5
Insular Africa	1	58,200	13,200	11,700	200	-1.2

(all figures in thousand hectares)

Table 3. - Preliminary estimates of tropical forest area and rate of deforestation for 87 tropical countries, 1981-90. (From: *World Resources 1992-93* by Allen L. Hammond (Editor-in-Chief). Copyright © 1992 by the World Resources Institute. Reprinted by permission of Oxford University Press, Inc.)

In this activity, students will examine the extent and impact of biomass burning and deforestation in Brazil as an example of the global problem.

Materials: overhead projector; transparencies of Brazilian forest fires, U.S., and forest fire dot patterns; copies of satellite photos of biomass burning in the Amazon 1988 and 1973.

Procedure:

1) Make transparencies of Figures 2 - 4, and display the outline of Brazil in comparison to that of the United States. The area of Brazil is 8,511,965 km^2; the U.S. is 9,372,614 km^2. The two country outlines (U.S. without AK and HI) are drawn to the same scale in Figures 2 and 4, so students can begin to visualize the size of Brazil.

2) Display and examine the Figure 2 transparency. This figure illustrates the location and number of fires burning in the Brazilian forests on September 1, 1987. Forests were being cleared for various reasons, and students should investigate these using current articles from the library.

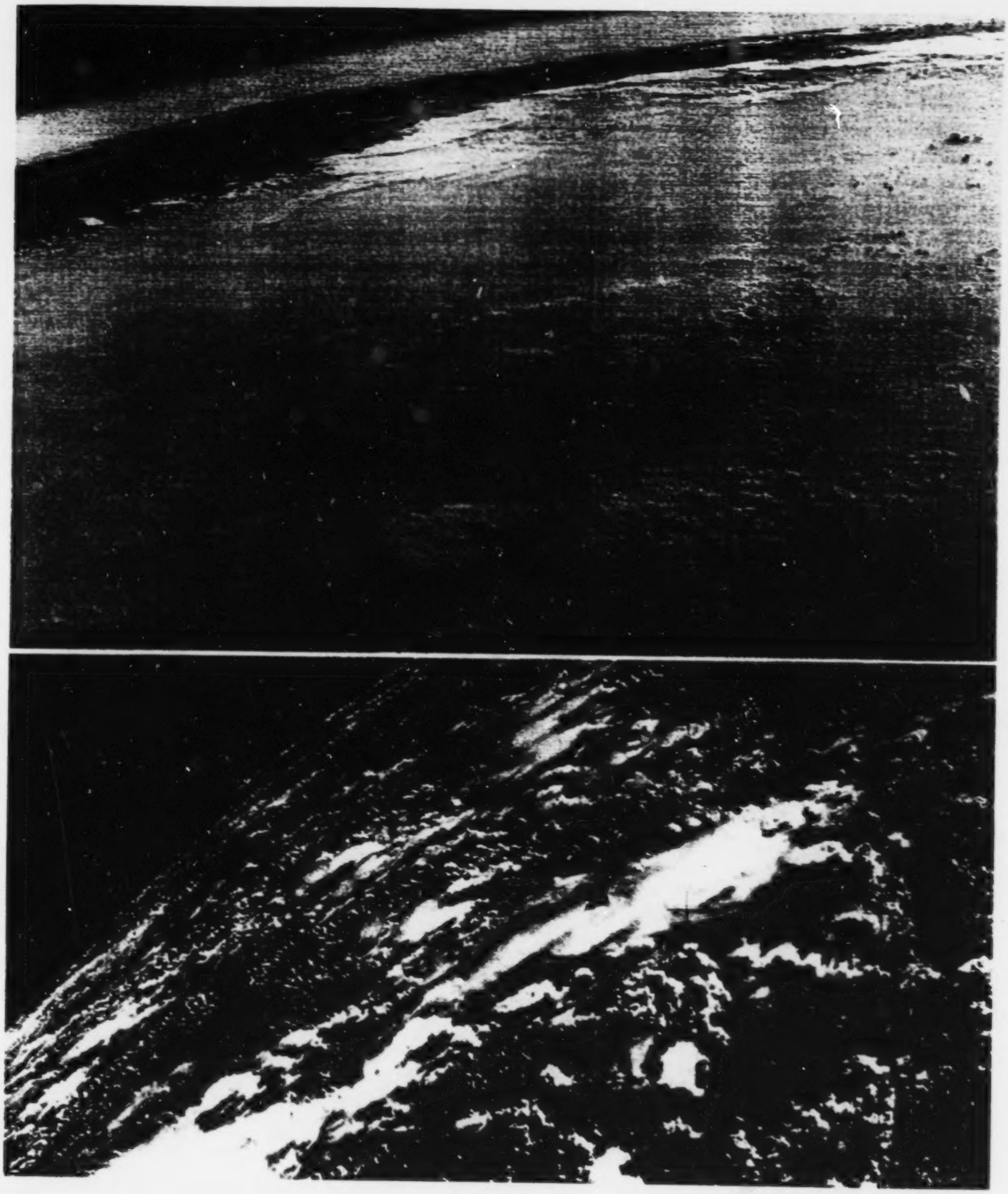
3) When the students have discussed the extent of the Brazilian fires, take Figure 3 transparency and overlay it on the U.S. map outline, Figure 4 transparency. Rotate the dot pattern so that as much as possible is within U.S. borders. To see the extent of the burning section in relation to the number of states in an equal size area of the U.S. is a dramatic demonstration of the extent of the problem.

4) A pair of satellite photos taken over Brazil in 1973 and 1988 are located on page 182. Study the photos carefully, especially the cloudy material in each. Discuss the following question with the students:

   a) how are the photos different from each other? Because of sensors in the satellite imaging system, scientists know that the white material obscuring the land in the bottom photo was not clouds, but smoke from fires below.

   b) what global atmospheric impact could such an amount of smoke have?

Invite students to hold these photos and the fire extent map as a "freeze frame" in their minds while they approach the next activity.



Two photographs illustrating the magnitude of difference in biomass burning of the Amazon rain forest between June 1973 (bottom) and September 1988 (top). (Source: *Earth in Space*. 1991. 3 (5) : cover page.)

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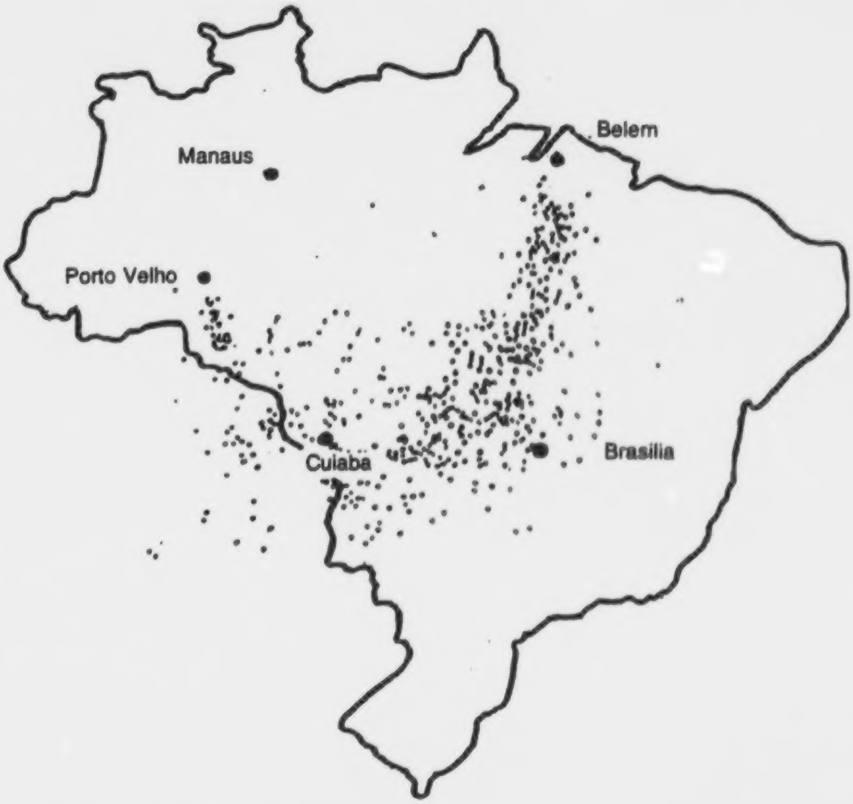
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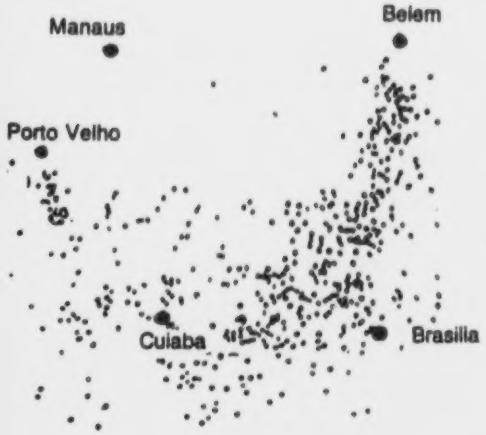
Figure 2. - A map of Brazil, showing the location of forest fires in the country. (Same scale as the U.S. map.)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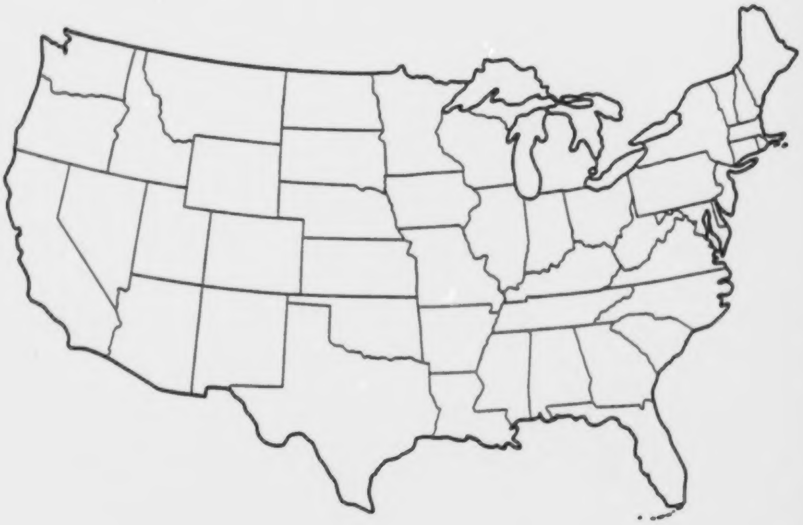

Figure 3. - The dot pattern of forest fires from Brazil. Each dot represents a forest fire.

Figure 4. - A blank map of the contiguous United States. (Same scale as Brazil.)

(Reprinted from *Science Activities*. 1992. 29 (1): 25 - 30.)

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Activity C: What are the effects of deforestation?

The loss of tropical forests impacts the Earth's systems in many interacting and complex ways. Some of the possible effects of deforestation include:

a) soil erosion and soil infertility;
b) loss of biodiversity;
c) increase in surface albedo;
d) increase in carbon dioxide levels;
e) a change and reduction in precipitation patterns;
f) increase in global surface temperatures.

In this activity, groups of students will choose one of the above possible effects of deforestation and develop a learning station to teach the rest of the class about the effect.

Materials: overhead projector; transparencies; landsat photographs; library resources or computer databases for information on each topic.

[Landsat photographs are available from EROS Data Center, U.S. Geological Survey, Sioux Falls, S.D. 57198. Ask for current maps and prices for any of the countries listed in Table 2 which would show the effects of deforestation. Check references list at the end of the activity for library resources or computer databases. However, students should complete some investigative research of their own. There is a great deal of information available on deforestation in recent periodicals.]

Procedure:

1) Assign one of the six effects of deforestation to each group of 4 or 5 students. Students should prepare an interactive learning station on their topics based on the following guidelines. The interactive learning station is defined as an area where active learning occurs, the students should have some experiment or learning simulation so that the visiting students are involved in an active learning situation.

A) (2 days) Allow the students time to research the topic and develop a variety of ways to demonstrate their findings on how deforestation can cause the effect. The explanation should be based on scientific evidence. It should be a factual presentation which clearly illustrates the evidence. Diagrams, charts, demonstrations, experiments, computer hypercards and pictures should be a part of the presentation in their interactive learning station.

[Use the reference list at the end of the activity to begin the research process.]

B) (1 day) Once the interactive learning stations are complete, each group of students should visit each station. Full instructions should be available at

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each station on any demonstration, computer program or other type of activity at the station. A one page handout should also be available at each station summarizing the students' findings.

> [For example, a demonstration for soil erosion could use 2 trays of soil, one with grass on it, the other without any vegetation. The students are instructed to pour some water on the soils and note the resulting amount of runoff and turbidity. A biodiversity interactive learning station may have a HyperCard computer program on the loss of organisms for the different layers of the tropical rainforest. Instructions should be available for its use.]

Evaluation:

After all the learning stations have been reviewed, the students will construct a concept map on the effects and implications of deforestation.

In advance, produce for the group 3" x 5" cards from recycled paper as follows:
1 card labeled DEFORESTATION (white or red);
20 cards labels MORE (light color, such as yellow);
20 cards labeled LESS/FEWER (same color as MORE);
35 - 40 impact cards with items that are likely to change as a result of biomass burning or deforestation (different color, so they are readily seen in the map).

Each group should spread the impact cards out over a large table. Placing the DEFORESTATION card at the top or the center, the students should select from the impact cards possible effects and implications of deforestation. These impact cards are joined to the larger DEFORESTATION card with the linking words, MORE or LESS. Other linking words may be used also. Groups can prepare a written or oral presentation of their maps, analyzing the thinking about interrelationships that produced the array.

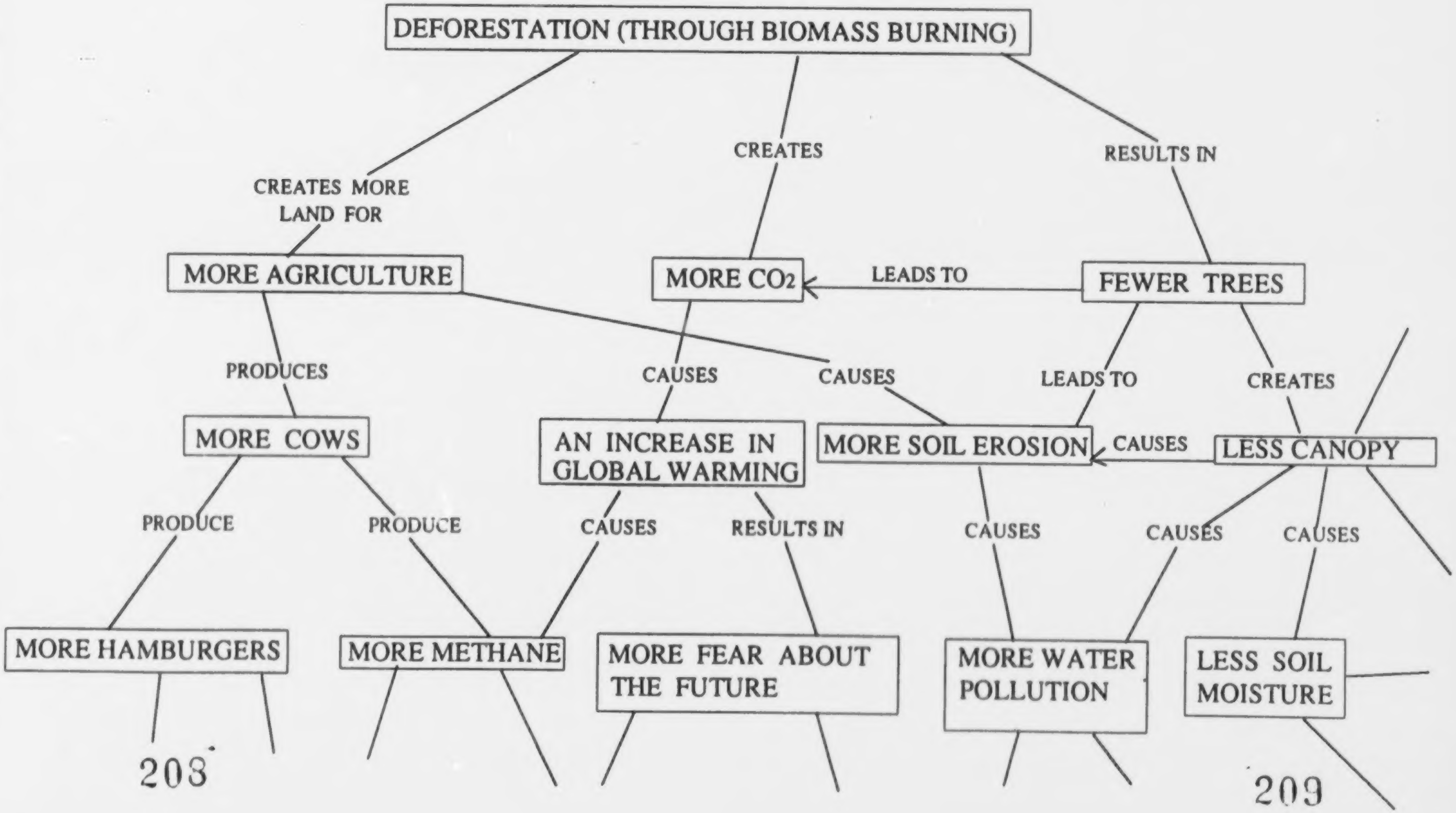
For example, they may decide that DEFORESTATION caused by biomass burning leads to MORE CO_2, or FEWER TREES. Students must be able to justify the position of the cards they add, and their choice of MORE or LESS as the impact. An example is given on page 187.

Think broadly in developing the impact cards. They should include both scientific impacts and social changes. Some possible impact cards might include

rainforest
carbon dioxide
sunlight
cows
"green medicine"
parrots
earthworms
clouds
water pollution
color
fear
endangered species
wetlands
trees
air pollution
canopy
hamburgers
disease
roads
income
drinking water
erosion
global warming
peace
extinctions
storms
oxygen
soil moisture
biodiversity
fuelwood
agriculture
native people
insects
tourism
shade
beauty
cooperation
rubber
cars

As students use these cards, it will become apparent that there are various interpretations of the impacts. For instance, there are clearly more clouds, produced by smoke from biomass burning, and some will note that leads to less sunlight. However there is also no canopy, so more sunlight can reach the ground, and there could be fewer rainclouds because no moisture is being added to the atmosphere from transpiration. All interpretations should be discussed. It is the varied correct interpretations of science that lead to uncertainty among decisionmakers. This is an important concept for students to discuss.

This mapping technique is modified from one developed by Zero Population Growth to demonstrate changes resulting from overpopulation. It can be modified for use in other interdisciplinary topics as well, such as global warming or disposal of toxic chemicals. Suggested uses include introduction to a new topic and how it relates to those previously studied, or as a culminating activity to draw all aspects of the study together. It would be an interesting evaluation to take a polaroid photograph of the concept map created at the beginning of a unit and compare it with the map produced at the end of the unit.


DEFORESTATION (THROUGH BIOMASS BURNING)
CREATES MORE LAND FOR
CREATES
RESULTS IN
MORE AGRICULTURE
MORE CO2
LEADS TO
FEWER TREES
PRODUCES
CAUSES
CAUSES
LEADS TO
CREATES
MORE COWS
AN INCREASE IN GLOBAL WARMING
MORE SOIL EROSION
CAUSES
LESS CANOPY
PRODUCE
PRODUCE
CAUSES
RESULTS IN
CAUSES
CAUSES
CAUSES
MORE HAMBURGERS
MORE METHANE
MORE FEAR ABOUT THE FUTURE
MORE WATER POLLUTION
LESS SOIL MOISTURE

A Concept Map for deforestation and its implications. Note the presence of linking words. The lines emerging from the boxes signify that more linkages may be formed. Create your own concept map for deforestation.

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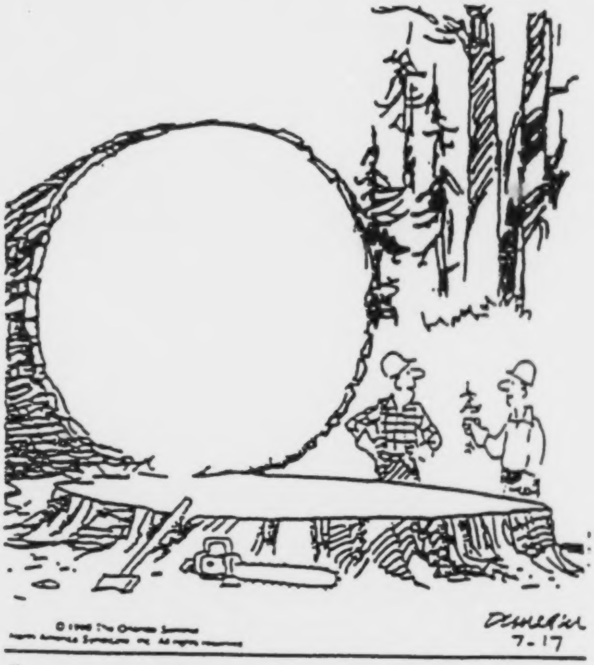
Extensions:

1) Forests possess an incredible biodiversity, and they have been extremely important in human development. Deforestation has occurred ever since the first humans walked on land. Vast tracts of Europe and America have been cleared of temperate and tropical forests for human development. Yet, as civilized industrialized nations we are recommending to the less developed countries to stop cutting trees.



" WELL, THAT'S THAT... DO YOU HAVE THE REPLACEMENT READY ?"

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North America Syndicate

You (or a group) are going to make a presentation to the government of a South American country to encourage it to halt or slow deforestation. Assemble your presentation with different types of media. Remember your presentation should include the biodiversity present, the appearance of deforested areas, how deforestation contributes to global warming, and other environmental problems, etc.

2) While most of the world's attention to the problem focuses on loss of tropical rain forests, loss of temperate forest habitat is also proceeding faster than it can be replaced. The controversy of the Spotted Owl has drawn attention to the deforestation of the northwestern U.S. However, in all the clamor and excitement over this endangered species, one important fact was overlooked. The fate of an entire complex, well developed ecosystem with thousands of other organisms, large and small, classified and undocumented, was at risk. Logging has played an important role in the history of the U.S. In 1872, over 1 million trees were felled in what is now

Adirondack Park and floated to the saw mills on the Hudson. President Ronald Reagan once stated that more trees were present in the U.S. during his terms than when George Washington was President. Examining these issues, trace the deforestation pattern in the U.S. since 1850. What have been the major influences on logging? What is the current status of the industry? What role does the National Forest Service play in logging? How are the forests and their products used? How important is logging to the national economy and some state economies? Think of some additional questions yourself.

3) Listen to some music concerning deforestation/trees/forests or read some Robert Frost poems (such as Birches, A Young Birch, The Sound of Trees). Express your reactions to the thoughts and feelings portrayed in the songs/poems. Then, answer the following questions:

(a) are forests of any value, other than commercially?
(b) why do people plant trees around our dwellings?
(c) is deforestation a problem? If so, is it something you should be concerned about?
(d) are the secondary effects of deforestation, i.e. loss of biodiversity, influence on climate, etc., easily solved? Support your answer with evidence.
(e) what can you do to help this situation?

Finally, express your feelings and emotions, in any form (i.e. rap, story, poem, etc.,) towards this topic from your experiences in this activity.

4) Rainforests took almost 350 million years to assemble, creating a vast storehouse of biodiversity, with intricate interactions between species and their environment. These areas are populated by over 50% of all living species, storing a wealth of yet untapped genetic information. Are rainforests worth saving for this reason? Or do they have an intrinsic value and a right to coexist with us on this planet? If they disappear consider what will be lost. How difficult would it be to transplant these communities to other areas within that same climatic region? Do humans possess the technology to do this transplantation? Would the climate have changed so drastically by present rates of deforestation that it would influence the transplantation?

5) Not all tree removal is destructive, of course. We depend on wood products for a variety of uses. Many people are involved in forestry and the use of forest resources. Trace the route of a tree from the moment it is felled to the endproduct and the consumer that uses it. List all the people involved in this process. Select one person and investigate his/her career, training required, financial rewards, etc.

6) Certain art forms have developed among natives of rainforests in the northwestern U.S. and in South and Central America. Identify some of these art forms. How do people use wood and other forest products in expressing their feelings about their home, culture, lifestyle (e.g. rainsticks)? Have loggers created art forms as an expression of their lifestyle?

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Teacher Background Information:

Findley R. 1990. "Will We Save Our Own?" *National Geographic.* 178 (3) : 106 - 136. An excellent article examining the situation of the virgin, old-growth forests of the U.S. It examines the question of deforestation and the loss of biodiversity in these store houses of life.

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Presents scientific observations on the current situation in the Amazon and its global consequences.

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Section 3 in this book deals with the tropical rain forests. A readable collection of essays which create a very detailed picture of the current crisis.

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Downeaster *Alexa*:

A fishery story.

We can learn a great deal about the sea, our planet and its people by listening to songs about ships and the sea. The sea has captured the human imagination and stirred its observers to art, literature and song. People across the centuries have recorded their feelings about the sea through these art forms. You may recall looking at Winslow Homer's paintings, or reading *Island of the Blue Dolphins*, or listening to the ballad that tells of "The Wreck of the *Edmund Fitzgerald*."

In this activity we will examine a 1989 song by Billy Joel, exploring its meaning for the singer and its ability to reveal to listeners some information about humans and environmental change. The maps, fisheries data, and sea temperature information were provided by the National Oceanic and Atmospheric Administration (NOAA) to give you an idea of the variety of important subjects this agency studies and how all the information must be considered at once when important issues are addressed. The concepts studied in this activity include: *use of historical data; population; impact of human technology on a population and it's use as a food source.*

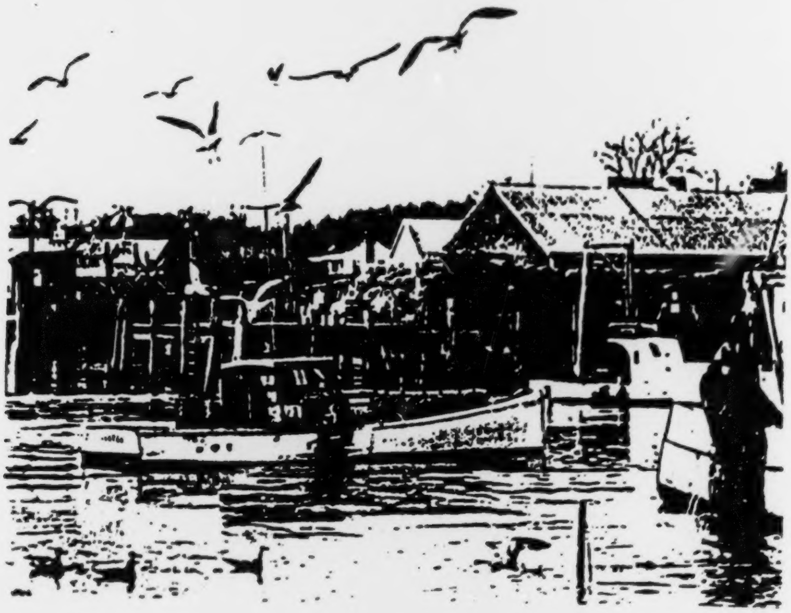

Figure 1. - A fishery scene, illustrating a downeaster boat.

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

Objectives: *When you have completed this set of activities, you should be able to:*

1) describe a major fishery of the North Atlantic (Activity A).
2) interpret the offshore characteristics of an area using a bathymetric chart (Activity A).
3) identify human and natural environmental reasons for changes in fish catch (Activity B).
4) analyze the relationship of global environmental changes to fish population changes (Activity C).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 1, 2, 3 and 7, however the following ESUs are covered in the Extensions — 4 and 5. Refer to the Framework for ESE for a full explanation of each ESU.

Activity A: What does the "Downeaster Alexa" reveal about a fishery issue?

Popular singer Billy Joel wrote "Downeaster Alexa" as part of his personal support for the struggling fishing industry of Long Island. Joel worked on an oyster boat there when he was young. The words of the song can give us a great deal of information about the events and people of the North Atlantic striped bass fishery. Apparently the singer sees problems with the system. Are these problems related to global environmental change? How can we tell?

Materials: lyrics of "The Downeaster Alexa"; recording from Joel's *Storm Front* album; NOAA map 13003 *(Cape Sable to Cape Hatteras, 1986).*

Procedure:
Read the words of the song as you listen to the recording. On your worksheet answer the following questions about the geography, culture and fishery conditions.

Geography

1) What places did the Alexa visit? List them in order; locate these on the worksheet map and connect them in order of travel.

2) Examine the map of oceanic characteristics and observe the depths of the places described in the song. How deep is the vessel's home port in Gardiner's Bay? What kind of feature is Atlantis? How deep is it? How far is it from the vessel's home port?

3) What kind of area is the singer fishing now compared to where he used to fish?

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Culture and Fishery Conditions

A typical "downeaster" (downeast work boat) is shown in Figure 1. There are several types, but most are of the same general shape and size.

4) Does the song indicate the size of the Alexa's crew? If there are others aboard, how would you describe the singer's position among them (that is, is he the captain, a crew member, navigator, or what)?

5) Is the Alexa crew fishing for fun or for a trophy size fish to mount and display (sport fishing) or fishing for a livelihood (commercial fishing)?

6) Analyze the financial status of the fisher who is singing. For example, does he make much money? How do you know? What things does he value in his life? What are his responsibilities?

7) According to the song, what influenced the fisher to choose this occupation? How likely is he to be successful in it? Why doesn't he give up fishing for some other line of work?

Fish and Fishing

Three kinds of fish are named in the song. Figure 2 contains some information about them that may be useful.

8) What kind of fish had the singer apparently been catching? Why doesn't he catch them now? What is his alternative?

9) Where are the alternative kinds of fish found (using your map)? Why does each fish pose a problem for the fisher?

10) According to the singer, how does fishing at present compare with previous years?

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The Downeaster Alexa

by Billy Joel

Well I'm on the Downeaster Alexa
And I'm cruising through Block Island Sound
I have charted a course to the Vineyard
But tonight I am Nantucket bound.

We took on diesel back in Montauk yesterday
And left this morning from the bell in Gardiner's Bay
Like all the locals here I've had to sell my home
Too proud to leave I worked my fingers to the bone

So I could own my Downeaster Alexa
And I go where the ocean is deep
There are giants out there in the canyons
And a good captain can't fall asleep

I've got bills to pay and children who need clothes
I know there's fish out there, but where God only knows
They say these waters aren't what they used to be
But I've got people back on land who count on me

So if you see my Downeaster Alexa
And if you work with the rod and the reel
Tell my wife I am trolling Atlantis
And I still have my hands on the wheel

Now I drive my Downeaster Alexa
More and more miles from shore every year
Since they told me I can't sell no stripers
And there's no luck in swordfishing here

I was a bayman like my father was before
Can't make a living as a bayman anymore
There ain't much future for a man who works the sea
But there ain't no island left for islanders like me

"The Downeaster 'Alexa'" by Billy Joel
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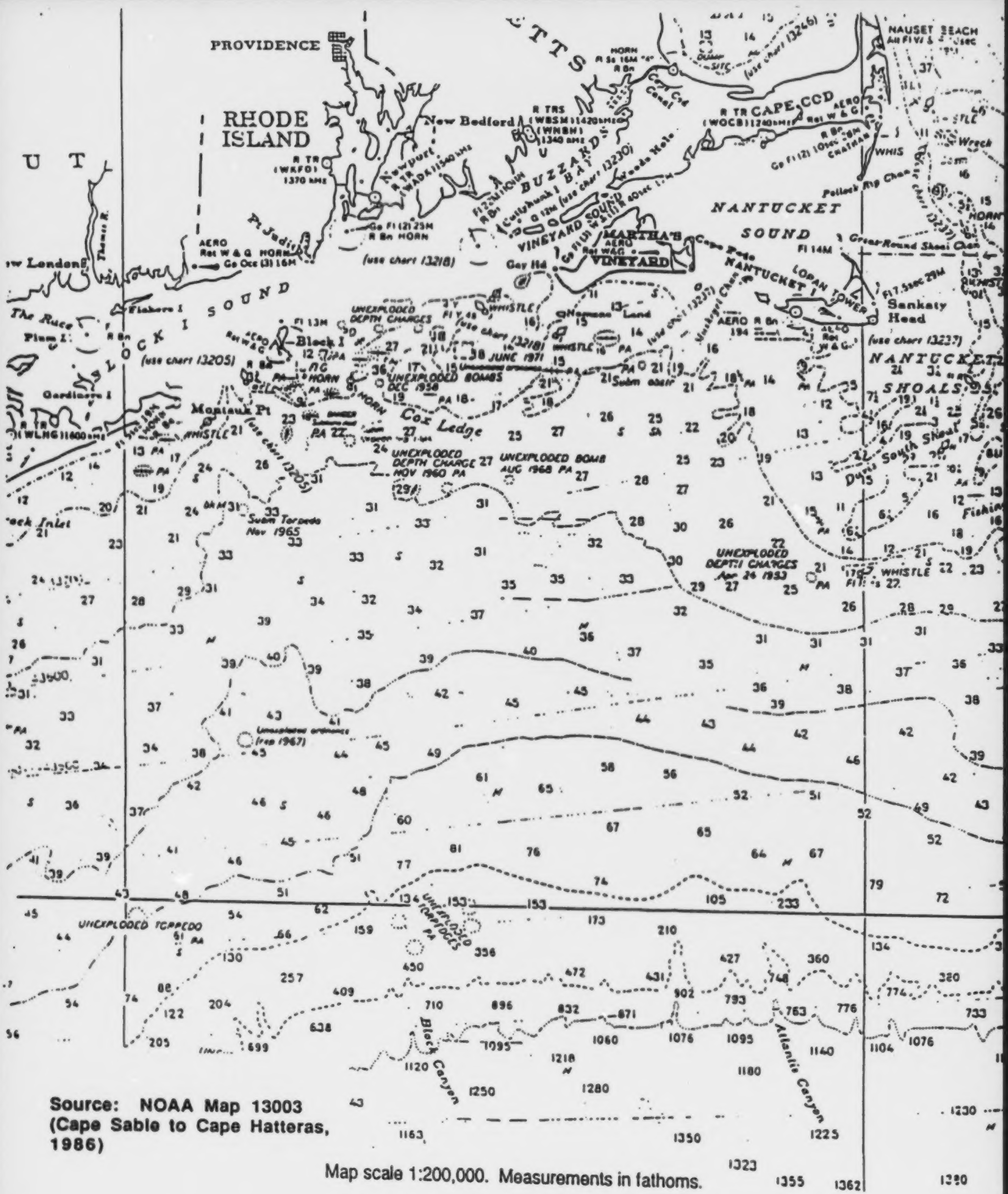
PROVIDENCE
RHODE ISLAND
New Bedford
Newport
Pt Judith
BUZZARDS BAY
CAPE COD
Cape Cod Canal
NANTUCKET SOUND
VINEYARD SOUND
MARTHA'S VINEYARD
Gay Hd
NANTUCKET I
Sankaty Head
NANTUCKET SHOALS
South Shoal
BLOCK I SOUND
Block I
Montauk Pt
Gardiners I
Plum I
The Race
Fishers I
New London
Thames R
Cox Ledge
Nomans Land
Muskeget Chan
Pollock Rip Chan
Great Round Shoal Chan
NAUSET BEACH
UNEXPLODED DEPTH CHARGES
UNEXPLODED BOMBS DEC 1958
UNEXPLODED DEPTH CHARGE NOV 1960 PA
UNEXPLODED BOMB AUG 1968 PA
UNEXPLODED DEPTH CHARGES Apr 24 1953
UNEXPLODED TORPEDO
UNEXPLODED TORPEDOES PA
Unexploded ordnance (rep 1967)
Subm Torpedo Nov 1965
Block Canyon
Atlantis Canyon

Source: NOAA Map 13003 (Cape Sable to Cape Hatteras, 1986)

Map scale 1:200,000. Measurements in fathoms.

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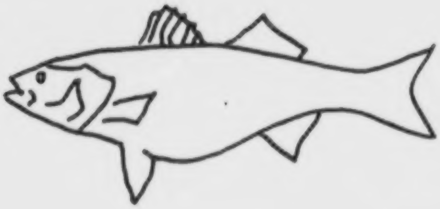
Striped Bass ("striper")

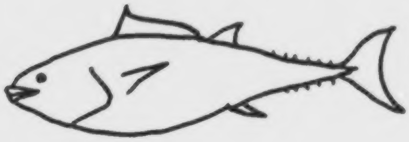


Size: adults 20-100 lb.; most bass of 30lb or more are females

Range: nearshore waters (to 4 miles) of eastern U.S; concentrations in Chesapeake Bay and Cape Cod/Gulf of Maine; temperature dependent, 19 - 23°C

Value: a leading game fish in North Atlantic; Commercial catch regulated since 1982.

Bluefin Tuna ("giants" in the song)

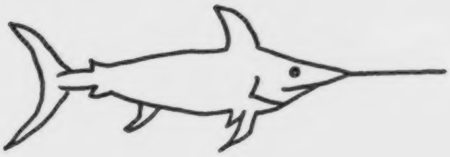


Size: adults up to 10 feet, 2000 lb.;

Range: mostly deep offshore waters; ranging as far north as Newfoundland in summer.

Value: prized by commercial and sport fishers: edible fighting fish.

Swordfish



Size: 6 - 15 feet, up to 1200 lb.

Range: lives in all warm seas.

Value: Prized by sport fishers for trophy; harpooned commercially as food fish.

Figure 2. - Three types of fish named in the song 'The Downeaster Alexa." (Mariners still use English measures rather than metric.)

Activity B: What causes the decline of a fishery?

Materials: data in Table 1; graph paper, pencil and pen or two colored pencils.

Procedure:

Make a graph of the total number of pounds of striped bass caught in U.S. waters of the North Atlantic since 1965. Answer the following questions.

1) In what year were the most stripers caught in US waters? When was the catch the lowest? Describe the general trend of the graph up to the present. What does this suggest about the size of the striper population in these waters?

2) Make a list of possible factors that can cause fish populations to change as they do in the graph. You may be able to get some ideas from the activity called *Yellow Perch in the Great Lakes.* Consider climatic effects, human impacts, water characteristics, predator-prey interactions, etc., and suggest specifically how each factor would contribute to fish population changes.

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[See Teacher Information page following the Activity.]

3) If possible, collect historical records of the factors you have identified. Do their trends relate to those of the striper catch?

	A	B	C	D
1	YEAR	Total Catch	MA Catch	NY Catch
2	1960	8550	129	731
3	1961	9461	210	910
4	1962	8611	589	657
5	1963	9288	480	673
6	1964	8557	522	995
7	1965	7710	463	740
8	1966	9075	585	1050
9	1967	10469	662	1630
10	1968	11104	874	1551
11	1969	12397	1038	1535
12	1970	11134	1344	1338
13	197	7821	749	1184
14	1972	10105	1174	836
15	1973	14733	1368	1741
16	1974	11017	1258	1409
17	1975	8833	1360	1184
18	1976	6536	1360	851
19	1977	5520	1185	766
20	1978	4589	860	1122
21	1979	3458	695	570
22	1980	4652	887	598
23	1981	4262	708	822
24	1982	2429	643	471
25	1983	1674	230	296
26	1984	2933	107	595
27	1985	1232	119	469
28	1986	337	96	
29	1987	431	78	
30	1988	407	80	
31	1989	205	172	
32	1990	823	148	82

Table 1. - Striped bass commercial landings (thousands of pounds), 1960-1990.

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Dr. Charles Coutant of the Oak Ridge National Laboratory has used general circulation models to predict changes in striped bass numbers and range if CO_2 were doubled and the earth's climate warmed. The "thermal niche" of adult striped bass is about 19 - 23°C. Juveniles are usually found in warmer water, but adults avoid 25°C and higher. Bass migrate up and down the coast as seasonal temperatures change.

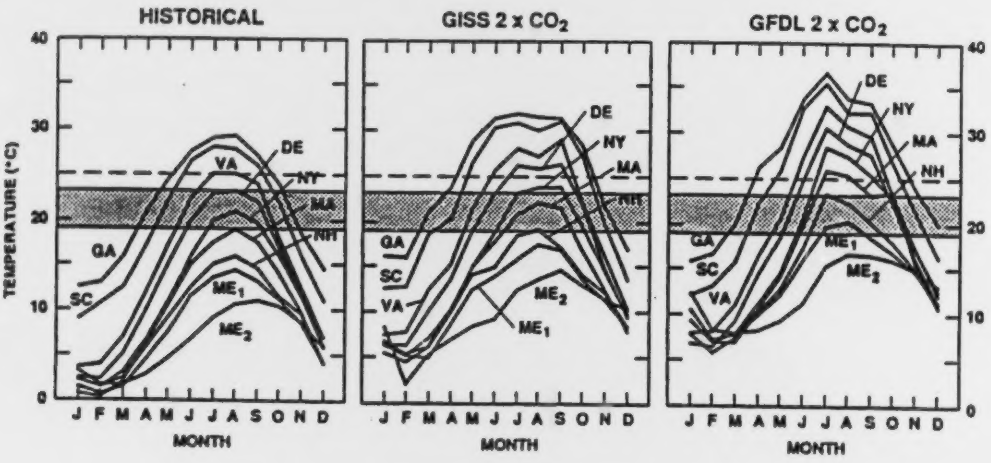

Figure 3. - **Atlantic coastal water temperatures, historical and as projected by two general climate models (GISS, GFDL) that simulate a climate with a doubled CO_2 concentration. Dashed line indicates the upper avoidance temperature for adult striped bass (25°C); shaded area is the striped bass thermal niche (19 - 23°C). (Source: Coutant, *Transactions of the American Fisheries Society*, 119 (2) : 240 - 253, 1990)**

4) Climate models predict a northward shift of water temperatures (Figure 3) and this can be used to forecast where the fish will be found in the future. Study the model predictions. (Also refer to 'Understanding Climate Models' fact sheet, available in the back of this book.) If a fisher goes out from Long Island in the year 2020, what is the possibility of a good catch of striped bass, compared with today's catch?

5) Look at the graph of striped bass catch from 1930 - 1960 (Figure 4) and compare it with the one you constructed from Table 1. Is the current trend an unexpected one? What forces are acting on the bass population now that were probably not as important earlier?

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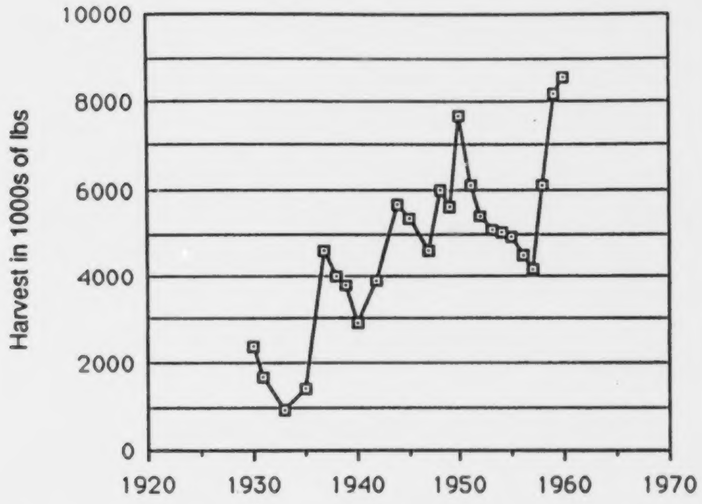

Figure 4. - Striped bass landings in the U.S., 1930 - 1960.

6) At present, striped bass are not found in the Great Lakes, although their physiology would allow them to live in fresh water. Look at a map of North America and note where the Great Lakes empty into the sea. From what you have learned in Activity B, discuss why striped bass haven't entered these waters yet. If climate changed to warmer, predict what could happen. Compare your prediction with what has happened with other Great Lakes invading species.

Activity C: How many fish should be caught?

All of the fish named in *The Downeaster Alexa* song are being **regulated**; in other words, rules have been made so that fish catches can only reach a specified quota. This will ensure that enough fish are left to continue the population. Fishery managers call this a **sustainable yield** of fish. Coastal states can make rules for fish caught within three miles of land. The federal government regulates fishing from three miles to 200 miles offshore (the Fisheries Conservation Zone, FCZ).

Materials: graph constructed in Activity B; Figures 5 - 6; Chart A; pencil or pen; fishery regulations in Table 2.

Procedure:

Answer the following questions on your worksheet:

1) Some fishers would say that regulations on fishing are responsible for the decline in fish catch, not a decreasing number of fish available in the water. Fishery managers say low catches prove the population is in need of protection (regulation). Who is correct? Describe the kinds of evidence you would need to decide which was the more correct interpretation of the declining catch.

2) On the graph you did for Activity B, plot the New York or the Massachusetts catch. Does the graph of the state catch show the same trend as the US graph? Describe how they are related or different.

3) If you were a commercial fisher in New York or Massachusetts, could you use this graph to argue for less regulation of your catch? Why or why not?

Though the magnitude of change is not so dramatic in the states, New York and certain other states have closed the fishery for some years and reopened in others. Examine Table 2, a summary of the fishery regulations in 1990.

4) Look at the graph of bass landings by distance from shore (Figure 5). Does it appear that commercial fishers would benefit if they were to go farther from shore to catch stripers? Besides sailing farther, what other changes would probably be required for offshore fishing? Which of the 3 kinds of fish in Activity A are most likely to be caught farther offshore (in deeper waters)?

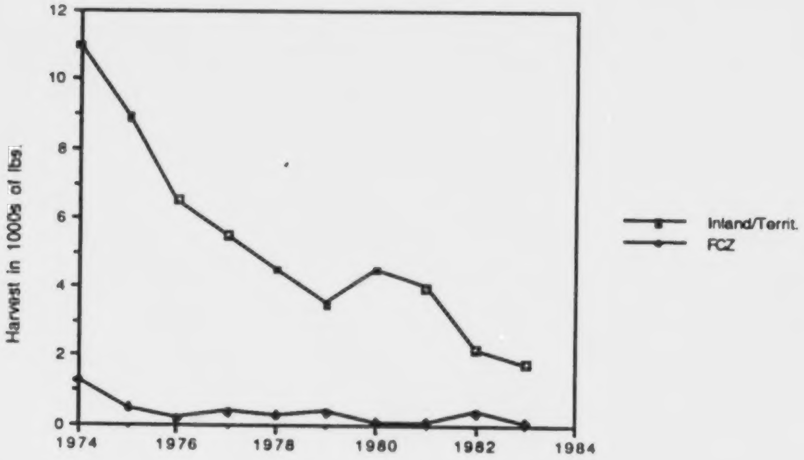

Figure 5. — **Striped bass harvest by year for inland waters and FCZ (200 mile zone).**

The regulations on striper fishing are based on the size of the fish and the age at which they become sexually mature (able to spawn). Female striped bass differ from males in size. Males rarely exceed 11 years and 30 pounds. A female at 16 years could weigh more than 40 pounds. Complete Chart A as follows to compare the impact of fish sizes on the potential for population growth.

5) If a day's catch is 100 stripers, half male and half female, all about 12 inches long, what proportion of males will have had a chance to spawn? What percentage of females might have spawned? At what fish size and age would most of the males have had a chance to spawn? At what age would most females be spawning?

6) Assume that in one spawning, 1 million eggs are produced and 0.5 million fry emerge. If only larger, therefore older, fish can be caught, how will the fishers

ultimately benefit from letting the fish grow larger? Fill in Chart A to demonstrate this.

7) Since most males are mature before females, the continuation of the population is based on how big the females are when they are caught. Review the regulations for the Atlantic states in Table 2. What do the differences suggest about the health of the fisheries in these states?

8) Analyze the benefits of regulating the striped bass fishery, both to the fishers and to the fish population. Identify any drawbacks that might emerge from such regulation.

Age of fish at catch	Size of Female	% of Fs spawning	# spawns per female X	# young per age per year	Fishery benefit X 0.5 = (fish added to pop.)
2	12"	0			
3	16"	0			
4	20"	25			
5	10 lb	75			
6	18 lb	95			
7	25 lb	100			
8	35 lb	100			

(NOTE: Striped bass are known to live to be 30 years old!)

Chart A. - Contribution to striped bass population by adults of different sizes

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State	Size Limits	Cap (1,000 lb)	Seasons[1]
ME	no fishery		
NH	no fishery		
MA	36" minimum	160	1 Jul - 30 Sep
RI	18" minimum 26" maximum (40" maximum for gear other than trap net)	35[2]	
CT	no fishery		
NY	24" minimum 28" maximum	128[2]	1 Sep - 15 Dec
NJ	no fishery		
PA	no fishery		
DE	28 " minimum	34	18 Mar - 31 Mar
MD			
Bay & River	18" minimum 36" maximum	319	12 Nov - 31 Jan[1] (includes all gears)
Ocean	28" minimum	25	2 Jan - 31 Jan
PRFC	18" minimum 36" maximum	156	various weeks during Sep, Oct, Nov, & Dec (total of 52 days)
DC	no fishery		
VA			
Bay & River	18" minimum 36" maximum	211	5 Nov - 9 Nov
Ocean	28" minimum 36" maximum		
NC			
Ocean	28" minimum	96	12 Feb 19 Feb - 23 Feb 26 Nov - 23 Dec

Note: More detailed information may be found in the text under state regulations.

[1] All seasons are calendar year 1990, except for Maryland Bay and River, which extended into 1991.

[2] Caps were reduced by ASMFC to offset the effects of slot limits with minimum size limits less than 28" on coast.

Table 2. - Summary of state harvest regulations on the commercial fishery for striped bass for 1990. (Source: NOAA, *Emergency Striped Bass Research Study Report for 1990.*)

9) Compare the history of whaling with the problem of what size of striped bass can be caught (Figure 6). What has happened to the largest species of whales? How could we prevent similar problems with striped bass?

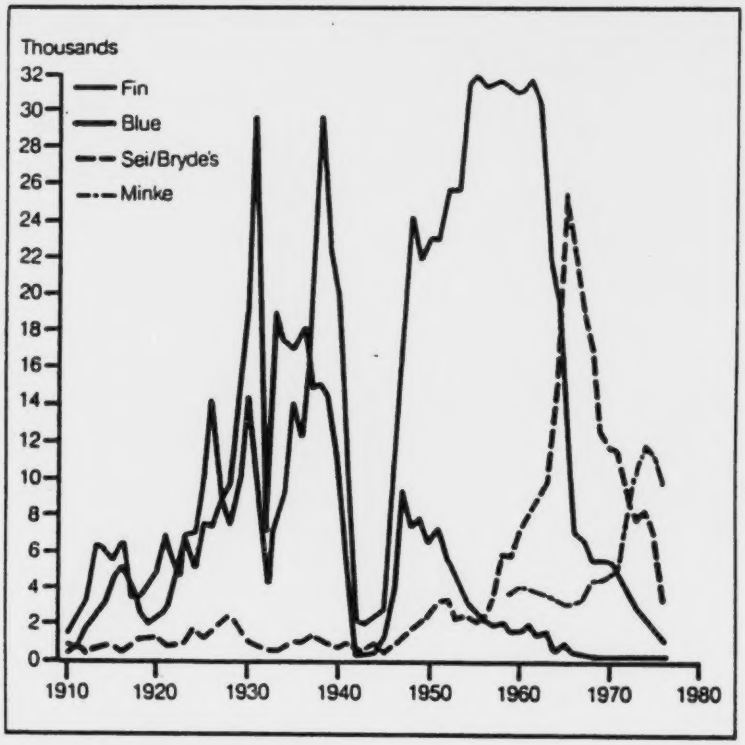

Figure 6. – World catches of five whale species, 1910-1976. (Source: Frost, *Whales and Whaling*, 1978.)

Review the Downeaster *Alexa* lyrics in light of what you now know about the striped bass fishery. Consider how much can be learned from a well-constructed art form such as this song. In the plight of a bass fisher we have found information connecting all the Earth systems: hydrosphere, atmosphere, lithosphere, and biosphere. Draw a concept map illustrating the relationships important to the *Downeaster Alexa*.

Is there a fishing industry (commercial or recreational) in your area? Examine the industry in your locality in light of what you have learned from this activity.

Extensions:

1) Fish are dependent on the interaction of the different subsystems of air, land, ice, water and life to live. Select one of the three species of fish from this activity and investigate its life cycle. Show how an alteration in one of the systems (besides global climate change) would impact the life cycle of the selected fish species.

2) Compare what you have learned in this activity, particularly that knowledge concerning the fisher's career, with a fisher on a large trawler or floating fish factory. What are the economics involved in these two different types of fishing? Compare the daily catch of each. Do you think that fishers like those in the song will survive economically? (The *National Geographic* article "Bering Sea" can be used in this extension.)

3) Commercial fishing is another industry that is dependent on a natural resource. Is this resource being used wisely? How is it regulated? Many people wonder if it is safe to eat fish because of the various chemicals flowing into rivers and eventually pouring into the sea. Is it any less safe than eating vegetables that have been sprayed or meat that has been produced on a factory farm? Like all systems on this planet, life has evolved over a long period of time, many millions of years. Different life forms have adapted to their environment. Is modern technology changing the environment so fast that species, such as fish, cannot adapt to this altered environment? Support your answer with evidence.

4) Many inland fishing areas are threatened by pollution, while other areas have been over-fished. Such areas may be re-stocked by the Fish and Game Divisions of the Department of Natural Resources of those states. How can you relate what you have learned in this activity concerning over-fishing, regulation of catch size, etc., to this situation?

5) Commercial fishers use drift nets. These nets catch large numbers of fish, but they also catch other marine species, such as dolphins, sharks, turtles, which become entangled in the netting and die. Investigate the damage that is caused by these nets and what has been done to try and stop their use.

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Additional Teacher Notes:

Hypothesis	**Research**	**Summary**
Contaminants	*In situ* and onsite bioassays in spawning rivers.	
	Maryland Nanticoke 1984-90 C & D Canal 1985-90 Choptank 1987-90 Potomac 1986, 1989-90	Toxic conditions in some rivers in some years. No single contaminant is consistently responsible for mortality. Point source discharge has been implicated.
	Virginia Rappahannock 1989-90 Mattaponi 1989-90 Pamunkey 1989-90 James 1989-90	Survival generally high. Metals concentrations much lower than in Choptank and Nanticoke Rivers
	Laboratory experiments: pH, aluminum and metals for various life stages	Highly sensitive to pH below 6.0 and aluminum concentrations. Salinity and organic acids ameliorate effects.
Starvation	Laboratory studies	Limited evidence of impact except perhaps in Potomac R.
Fishing Mortality	Extensive management changes. Simulation modeling.	Strong evidence of over-exploitation that reduced recruitment. Difficult to distinguish from effects of other factors.
Predation/ Competition (Larval Stage)	Exposed larvae to variety of predators in laboratory.	Numerous potential predators, but evidence in field data is lacking.
Climatic Events	Evaluated historical data on pH trends in major spawning rivers.	No evidence of systematic decrease in pH or increased frequency of low pH events. Historical information is insufficient to detect small changes.
Water Use Practices	Evaluated flow conditions invicinity of Cape Cod Canal	Evidence of transport out of Bay and entrainment of larvae. Overall impact is uncertain. Canal may serve as major egress for juveniles and adults from Chesapeake Bay.
Disease	Laboratory studies of IPN virus	Nonlethal, but striped bass can act as carriers. Potential disease problems in intensive culture, but much lesser problem in nature.

Summary of Emergency Striped Bass Study research on factors responsible for the decline of striped bass in Chesapeake Bay. (Source: NOAA, *Emergency Striped Bass Research Report for 1990.*)

Teacher Background Information:

Deuel, D., McDaniel, D. and Taub, S. 1989. *Atlantic coastal striped bass road to recovery.* Washington, D.C.: NOAA and US Fish and Wildlife Service. This is the most concise and easily understood of the references.

Phillips, J. H. c1991. *They're Back.* Maryland Department of Natural Resources, Tidewater Administration — Fisheries Division Tawes State Office Building Annapolis, Maryland 21401.
This brochure from the Maryland DNR documents the history of the striped bass in the area. It examines the life history of the fish, its spawning habits, growth rates, food sources and schooling habits. The author traces the decline of the fishery, the measures used to halt this decline and the current status of this fish species.

Bigelow, H. B. and Schroeder, W. C. 1953. *Fishes of the Gulf of Maine.* Fishery Bulletin 74, Vol. 53 : 389 - 404.
This is a more technical bulletin but is useful as various characteristics of the striped bass are outlined. The historical records of habits of this fish species are also documented. One section examines the periodic fluctuations in the distribution of the bass, using different historical sources.

References:

Coutant, C. C. 1990. "Temperature-oxygen habitat for freshwater and coastal striped bass in a changing climate." *Transactions of the American Fisheries Society.* 119 (2) : 240 - 253.

Fortner, R. W. and Leach, S. 1986. *Yellow Perch in Lake Erie.* OEAGLS Activity #9. Ohio Sea Grant Education Program. (Available from The Ohio Sea Grant Program, 1314 Kinnear Rd., Columbus, OH. 43212-1194.)

Frost, S. 1978. *Whales and Whaling. Volume 1.* Canberra: Australian Government Publishing Service. 32 - 33.

Hodgson, B. 1992. "Hard Harvest on the Bering Sea." *National Geographic.* 182 (4) : 72 - 103.

Rago, P. J., Dorazio, R. M., Richards, R. A. and Deuel, D. G. 1992. *Emergency striped bass research study report for 1990.* Washington, D.C.: US Fish and Wildlife Service and NOAA. USGPO: 1992-313-153:60019.

Richkus, W. A. 1990. *Source document for the supplement to the Striped Bass FMP. Fisheries Management Report #16.* NOAA Atlantic States Marine Fisheries Commission.

Setzler, E. M. and others, 1980. *Synopsis of biological data on striped bass, Morone saxatilis, (Walbaum).* NOAA Technical Report. NMFS Circular 433.

VIDEO:

Government of Canada, Department of Fisheries and Oceans, and Department of External Affairs. 1992. *Fragile Fishery.*

While not specifically dealing with the American Fishing Industry, this video does deal with many of the issues outlined in this activity and the concept of declining fish stocks.

Available from Department of External Affairs, Ottawa, Canada (613 992-1344).

Is sea level rising? Well, it depends . . .

For those who have a home or business on the coast, the prospect of a change in sea level is always threatening. Even short-lived events that change water levels such as Hurricane Hugo did in South Carolina in 1989 disrupt coastal life and can be very costly. With the variations in global climate that are predicted, changes in sea level will be inevitable. What will determine the impact of these changes?

As we learn more about Earth forces and changes, the most-asked about global climate change questions are changing from "what if" to "how much?" and "when?" and "where?" The most difficult questions are "when?" Models of climate change are organized to accept a given scenario — doubled CO_2 for instance — and to calculate all the relationships that will change under that new scenario until the parts of the system achieve equilibrium. The modelers ask questions that will automatically result in a 20-year or 100-year prediction, or a prediction for just one particular region. Models produce a global pattern from which scientists must select the portions useful for answering their own questions. In this activity we will look at some "where?" and "how much?" questions.

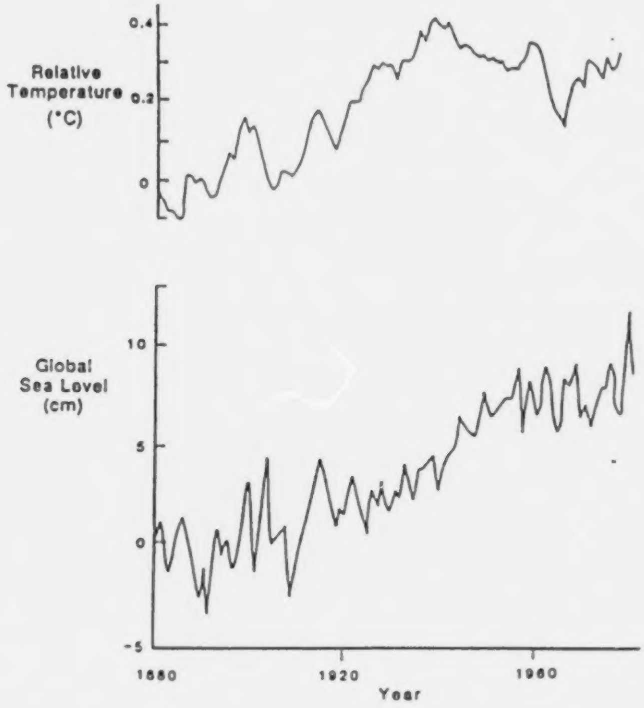

Figure 1. - **Sea level and Temperature Trends in the Last Century. (Source: U.S. EPA, *Greenhouse Effect, Sea Level Rise, and Coastal Wetlands*, 1987.)**

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with the support of The Ohio State University.

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Sea level models were developed more recently than atmospheric models but they are just as controversial. Identifying mean sea level is a major problem, because even though the oceans are all connected, variations in atmospheric pressure at different latitudes, as well as the Earth's rotation, Earth crustal movements, and ocean basin shape, affect the sea level at any given point. The method of determining "true" **eustatic** (global) sea level has changed recently so that older records need to be converted in order to interpret historic trends. In the data for this activity, the conversion has been done. To learn more about the reasons for the change, read the Whalen work listed in the reference section.

Historic Records. It is important to remember that sea level has been rising since the peak of the last glacial period 20,000 years ago. Mean sea level at the end of the glacial period was 100-150 feet below present sea level. Examine the graphs in Figure 1 which compare air temperature and sea level rise in this century. In just the last century, sea level has risen 12 cm. Air temperatures have also increased through time in the Northern Hemisphere, although the trend has not been as constant.

Modern Analyses. From existing analyses of models and scenarios, James Titus of the U.S. Environmental Protection Agency has developed the summary in Table 1. These studies, from the National Academy of Science and EPA, estimate the amount of sea level change that will likely result from thermal expansion and the melting of certain large glaciers. When the models are used to consider different scenarios for sea level rise, an interesting set of predictions emerges (Figure 2). The scenarios are plotted through the year 2100, although not all were in equilibrium by then.

Clearly, there is a range of possibilities for what could happen to sea level, but discuss with your classmates what a middle estimate might be. (Perhaps 1m rise occurring sometime between 2075 and 2100.)

The concepts studied in this activity include: *climate change models; sea level rise; and use of historic records in predicting new coastlines for the U.S.*

	Last Century	Next Century	
Source		NAS	EPA
Thermal Expansion	5 cm	30.5 cm	45.7 cm
Snow and Ice Melt	5 cm	40.6 cm	45-91 cm
Local Subsidence (east coast)	20.3 cm	20.3 cm	20.3 cm
Total (east coast)	30.5 cm	91.4 cm	106-152cm

Table 1. - Estimates of the sources and amounts of sea level change. (Source: EPA)

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Objectives: Upon completion of this activity students will be able to:

1) explain all the characteristics which influence sea level changes (Activity A).
2) describe how different global change models produce different scenarios of sea level changes (Activity A).
3) analyze data about historic sea level changes in an area (Activity B).
4) predict sea level changes and coastal effects in the near future (Activity B).
5) describe to others the sources of variability in sea level for a given region of the United States (Activity B).
6) evaluate alternative approaches to dealing with rising sea level (Activity C).
7) suggest appropriate mechanisms for abatement, prevention, and accommodation of sea level changes (Activity C).
8) identify facilitative and obstructive roles in group dynamics (Activity C).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3, 4 and 7. However, the following ESUs are covered in the Extensions — 1 and 5. Refer to the Framework for ESE for a full description of each understanding.

Activity A: Does future sea level depend on people's actions?

The set of relationships used to construct the sea level rise estimates is diagrammed in Figure 3. As an introductory activity, teams will dissect Figure 3 and examine the relative impacts of its parts. If a computer modeling program is available to the class, some students may wish to attempt a simple model. This would be an excellent addition to the activity.

> [STELLA is an introductory modeling program for Macintosh. An existing and less complicated program on climate change is available from Kern International, Inc. in Duxbury, MA. A global warming program in BASIC for Macintosh or IBM is available as part of a set of Computer Models of the Environment, by B.J. Korites. Introductory college level.]

Materials: copies of Figures 2 and 3.

Procedure:
Work in teams to investigate Figure 3 and its relationship to Figure 2.

1) Study the relationships in Figure 3. Trace the flow chart backwards from the SEA LEVEL RISE box, noting which pieces of the model are grouped together. Boxes with arrows going OUT are contributing their input to the receiving box. Be sure you understand what each of the inputs are, where they originate, and why they are placed in the model as you see them.

2) Mark each of the input boxes that is under direct control of humans. What fraction of the total input (number of boxes) do humans control directly? indirectly?

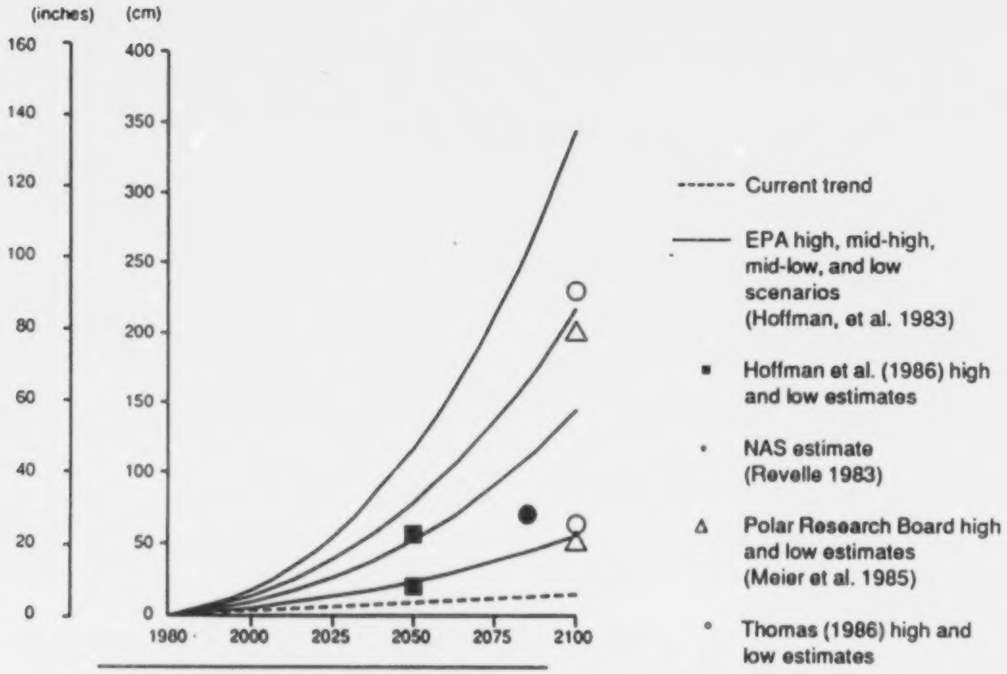

Figure 2. - Global sea level rise scenarios. (Source: Titus, *Greenhouse Effect, Sea Level Rise and Coastal Wetlands*, 1987.)

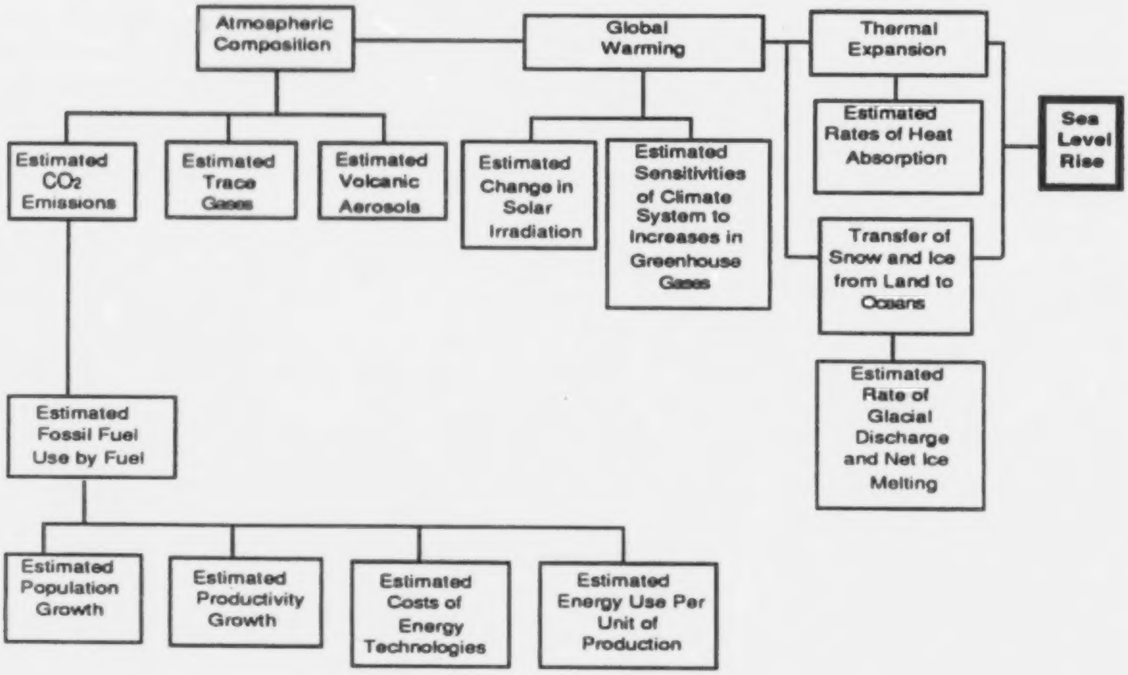
Atmospheric Composition
Global Warming
Thermal Expansion
Sea Level Rise
Estimated CO2 Emissions
Estimated Trace Gases
Estimated Volcanic Aerosols
Estimated Change in Solar Irradiation
Estimated Sensitivities of Climate System to Increases in Greenhouse Gases
Estimated Rates of Heat Absorption
Transfer of Snow and Ice from Land to Oceans
Estimated Rate of Glacial Discharge and Net Ice Melting
Estimated Fossil Fuel Use by Fuel
Estimated Population Growth
Estimated Productivity Growth
Estimated Costs of Energy Technologies
Estimated Energy Use Per Unit of Production

Figure 3. - Sea level scenario model represented as a flow chart.
NOTE — Other factors may influence this flow chart at any point or at any time. Remember that earth systems are dynamic and interactive, but are represented in a linear fashion. (Source: Barth and Titus, *Greenhouse Effect and Sea Level Rise: A Challenge for This Generation*, 1984.)

3) Can you think of other boxes that could be added? Are there other connections that could be made? Place them in your model in pencil and be prepared to discuss your reasons.

> [Some would maintain that the four lower boxes should be connected laterally because they may influence one another. Humans may also be able to directly affect incoming solar irradiation.]

4) Assume that all the inputs to a certain quantity, such as atmospheric composition, are additive. For example, the four lower boxes contribute to "estimated fossil fuel use by fuel type" as a sum of what is happening in the four boxes. Give each one an arbitrary initial value such as 5. Add the boxes that make sense to add, and get a total sea level rise. Then, double the value of one of the receiving boxes and recalculate. Is there much difference in sea level change? Suppose the boxes were multiplied instead of added. (This may indeed be the case.) How would the outcome be affected by doubling one?

5) Unfortunately, few of the components in the model would be operating alone in changing the system. With the entire class participating, each group should now increase 2, 3, or 4 related variables and predict a sea level outcome. Remember that the variables closest to the outcome may have had a large input and be more potent in effecting change than variables which operate from farther away in the model.

6) In some cases it might be possible to reduce one or more of the inputs. Select a potential input and tell how it might be decreased. Reduce its value in your model and recalculate. Check with other teams to see which variables they reduced. Could all of the human inputs be changed in this way?

7) Describe some sources of the variability in sea level models. In other words, what are some reasons for the differences in the predictions in Figure 2?

> [See Understanding Climate Models, located at the back of this book.]

Activity B: What local factors determine the extent of sea level rise?

While the models of eustatic sea level have to be a bit conservative because of the variability within the global system itself, local models can use very specific data on most of the factors that influence how local sea level will respond to eustatic changes. This activity examines site-specific changes in the past century and the present on U.S. shores.

Figure 4 illustrates the variability in observed sea level at various locations. We know that eustatic sea level is based on the global ocean and its characteristics, and all the world's oceans are interconnected. What is going on at these sites to make sea level so different?

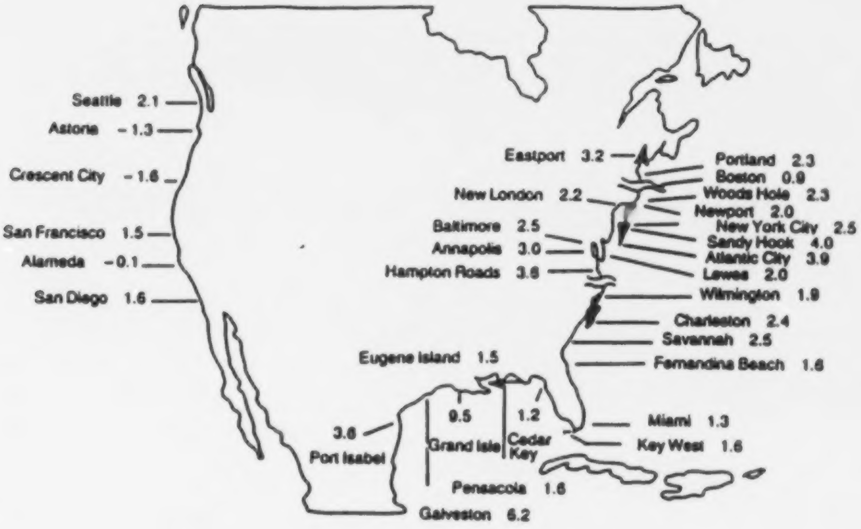
Seattle 2.1
Astoria -1.3
Crescent City -1.6
San Francisco 1.5
Alameda -0.1
San Diego 1.6
Eastport 3.2
New London 2.2
Baltimore 2.5
Annapolis 3.0
Hampton Roads 3.6
Portland 2.3
Boston 0.9
Woods Hole 2.3
Newport 2.0
New York City 2.5
Sandy Hook 4.0
Atlantic City 3.9
Lewes 2.0
Wilmington 1.9
Charleston 2.4
Savannah 2.5
Fernandina Beach 1.6
Eugene Island 1.5
9.5
1.2
3.6
Port Isabel
Grand Isle
Cedar Key
Miami 1.3
Key West 1.6
Pensacola 1.6
Galveston 6.2

Figure 4. - Site-specific U.S. sea level changes in mm/yr., based on data from 1940 - '80 as available. (Source: Fortner, *Science Activities*, 1992.)

Materials: articles about sea level change [teacher list]; NOAA book on Sea Level Changes in the US; "Sea Level Rise" fact sheet located at the back of this book; transparency film, washable markers, rulers; laminated topographic maps of shorelines near

Kodiak, AK	San Francisco, CA	south Florida
Galveston, TX	Charleston, SC	Grand isle, LA
Atlantic City, NJ	Hilo, HI	a coast near your school

Procedure:

1) This is a cooperative learning activity in which teams of students examine conditions affecting sea level in various parts of the United States. Each team will receive an article about its assigned coastal area, a topographic map of it, historical data for the region, and materials for demonstrating to the remainder of the class why sea level is changing as it is in their area. The goal of the team is to lead others to an understanding of sea level variability in their assigned area. This can be done through a standard presentation, simulated news broadcast, documentary, or other creative mode.

2) Team members assume the following roles:

Data technician -- analyzes NOAA data on historic trends in sea level by month in a recent year, and by year over the past recorded period. Develops graphs to show trends. Assuming eustatic sea level rise of one meter in 75 years, calculates amount of sea level change expected by the assigned area.

Cartographer -- Draws lines on maps to demonstrate what the expected eustatic rise of one meter in 75 years would do to land surfaces in the assigned

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area. Compares actual expected rise based on local events and factors. Identifies features that are threatened by sea level change. Identifies other maps that illustrate potential impacts.

Historian -- Studies article about sea level for the area and becomes expert on local historical influences (earthquakes, hurricanes, land subsidence, etc.)

Sociologist and Organizer -- Studies human impacts of sea level change in the area: how have people responded to changes, what is the extent of coastal development, etc. This person also gets all the team members together to develop a presentation for the class.

Use the points outlined in the sheet entitled, **"Decision-Making Problems Associated with Rising Water Levels"** to plan your arguments.

3) While the presentations, including their own, are being made, students should be alert to the possible answers for these questions:

a) What parts of the United States are subsiding in relation to sea level? Why is this happening? What will be the net effect of sea level changes in these areas?

b) What parts of the US are rising in relation to sea level? Why does this happen? What will be the net effect on sea level changes?

c) How do short-lived events influence sea level? Give examples.

d) What kinds of decisions do people in coastal areas need to be making to prepare for or lessen the impact of sea level changes? Examine the issue of the freshwater available to these communities before and after the sea level rise.

4) Following the presentation, the students should produce a map of the U. S. coastline in the year 2030. They should consider the financial and societal impacts of this projected rise in sea level.

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Sea level change articles for Specific Coastal Areas.

Coastal Areas — Many of these, as well as other areas, are included in studies reported in J.B. Smith and D. A. Tirpak, 1989. *The Potential Effects of Global Climate Change on the United States: Appendix B – Sea Level Rise.* (EPA-230-05-89-052) Washington, D.C.: USEPA (PM-220).

New Jersey:

Titus, J. G. 1990. "Greenhouse Effect, Sea Level Rise, and Barrier Islands: Case Study of Long Beach Island, New Jersey." *Environmental Management.* 18 : 65 - 90.

Florida:

Wanless, H. R. 1989. "The Inundation of our Coastlines." *Sea Frontiers.* September/October. 1989. 264 - 272.

Massachusetts:

Aubrey, D. G. and Graham, S. G. 1987. "Losing Coastal Upland to Relative Sea Level Rise: 3 Scenarios for Massachusetts." *Oceanus.* Fall. 17 - 22.

South Carolina:

Titus, J. G. 1984. "Planning for Sea Level Rise before and after a Coastal Disaster." In Barth, M. and Titus, J. G. (Editors). *Greenhouse Effect and Sea Level Rise: A Challenge for This Generation.* New York: Van Nostrand Reinhold. Chapter 8. 253 - 267.

National Oceanic and Atmospheric Administration/National Ocean Service. 1989. *Hurricane Hugo: Effects on Water Levels and Storm Surge Recorded at NOAA/National Ocean Service Water Level Stations.* Sea and Lake Levels Branch, Physical Oceanography Division, Office of Oceanography and Marine Assessment. November 30, 1989.

Louisiana:

Titus, J. G. 1990. "Greenhouse effect, sea level rise and land use." *Land Use Policy.* April, 1990. 138 - 153.

Alaska:

Spaeth, M. G. and Berkman, S.C. 1967. *The Tsunami of March 28, 1964, as Recorded at Tide Stations.* U.S. Department of Commerce, Environmental Sciences Service Administration. July 1967.

Satellite Image Maps for some coastal areas are available from USGS, Reston, Virginia 22092. Cost $3 (1991).

For further information on cost and availability of NASA ERTS-1 satellite images contact USGS, EROS Data Center, Sioux Falls, S. Dakota 51798.

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DECISION-MAKING PROBLEMS ASSOCIATED WITH RISING WATER LEVELS

LOCATIONAL DECISIONS

- Where to put private development and redevelopment
    - Housing
    - Factories
    - Resorts
    - Energy Facilities
    - Hazardous waste sites

- Public development decisions
    - Roads
    - Utilities
    - Port infrastructures
    - Parks
    - Bridges

- Purchase of lands for conservation

STRUCTURAL AND SITE DECISIONS

- How to build facilities
    - Their movability
    - Site contouring
    - Construction type and quality
    - Planned lifetime of structure

- R&D on how to improve options
    - Such as making structures more "sea level resistant"
    - Making structures more movable

- How to make low cost design changes to reduce adverse effects

PROTECTIVE MEASURES AGAINST FLOOD AND EROSION

- Protective facilities such as sea walls
    - height
    - type
    - foundation size (so they can be explained later)

- Beach nourishment decisions
- Vegetation planting and maintenance decisions
- River channeling and rechanneling decisions
- Land acquisitions set aside for public and private works for future protection
- Local zoning and other land-use controls to reduce development in wrong areas
- Flood protection requirements for hazardous facilities

DECISIONS ABOUT FLOOD MITIGATION PLANNING

- Evacuation plans
- Post disaster plans
- Insurance policies subsidies and costs

(Source: Good, *Greenhouse Warming and Sea Level Rise*, c1988.)

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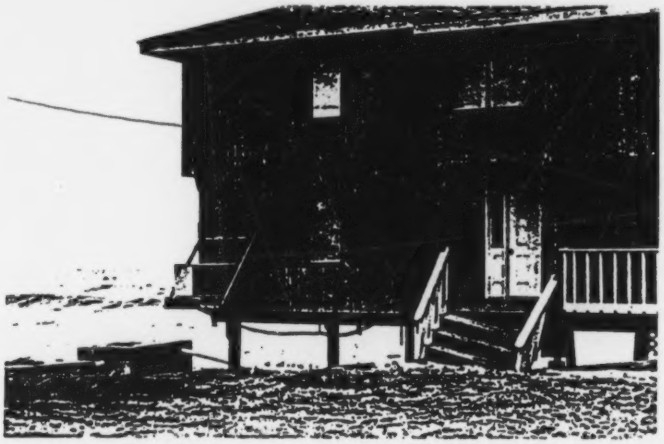
Activity C: How would you deal with changes in sea level?

In the previous activities we considered how sea level rise is associated with global climate change and how the local changes in sea level may vary because of other things going on in Earth systems in those areas. Most people are not content to let nature take its course, especially when nature is threatening to undo things that people have constructed and come to depend upon.



Sandbridge, VA, 1992: Beachfront home destroyed by natural processes of coastal erosion on a sandy shore.

John McPhee's book, *The Control of Nature,* gives numerous examples of the extent to which people will go to protect a faulty system that they have used as the basis for other faulty systems! In this activity, you will consider how people living in coastal areas of the U.S. (the areas studied in Activity B) make decisions to deal with natural phenomena and those associated with global climate change.

Materials: selected materials (maps, graphs) from Activity B; costumes to represent character roles chosen for this activity; podium, speakers' table with gavel, and seating for "townspeople."

Procedure:

1) As a class, select one of the localities studied previously as a site for a town meeting to discuss community response to sea level change. Based on the needs of the area, including its existing structures and growth potential, develop a proposal to be considered for dealing with sea level change. Examples might be:

   a) Nourish beaches with sand from other areas to preserve tourism.
   b) Abandon all lands and developments in the projected 75-year sea level range and begin building elsewhere.
   c) Build replacement marshes farther inland on coastal rivers.
   d) Construct sea walls to prevent encroachment of the sea.

Responses to climate-induced changes have been classified as being either **ABATEMENT**, to fix the problem or make it less of a problem; **ACCOMMODATION**, to learn to live with the problem and not try to change it; or **PREVENTION**, working to prevent the problem from happening.

Assume that for this activity there are some people who would be in favor of each of these responses.

2) Look at the list of "Decision-Making Problems Associated with Rising Water Levels." For your chosen area and proposal, identify types of people who might base their opinions in the town meeting on some of these decision points or possibly on their profession. A builder, for example, would have some interesting opinions on an "abandon it" proposal. A lawyer, scientist, travel agent, coastal property owner, environmentalist, all would have important viewpoints.

3) Students assigned to these roles will be backed by a group of supporters in the "community" who will help design testimony, suggest tactics, provide examples, or take appropriate action to make their opinions known in support of or opposition to the proposal.

4) The teacher will distribute instructions for additional roles in the group activity. These are behavioral roles that should be played within the character of the role assigned, both among the community supporters and the main speakers. Behavioral roles should not be discussed with other students.

Scenario: At the front of the room is a long table with five members of City Council seated behind it facing the audience of citizens. A podium is present for citizens to address the council with its concerns. Speakers can face Council or the audience at any time. Citizens should come to the podium before offering testimony at the meeting. A speaker has a maximum of 2 minutes for presentation, but may speak more than once. The Mayor (one of the five on Council) keeps time and order.

A member of the Council reads the proposal and calls for testimony on it from the citizens. Council hears all the speakers and then must makes a majority decision on the proposal.

Follow-up: Based on what they have observed as the town meeting progressed, students should complete the following:

1) List the arguments for and against the proposal. Classify each argument as being accommodation, abatement, or prevention. If other categories of arguments are needed, identify them with your class.

2) Identify your own position on the issue and justify it. What category does it represent and why? Would you adopt the same position for other sites with similar problems? Why or why not?

3) Did all groups of participants encourage the decision-making process? Identify some facilitating behaviors that people had. Identify some behaviors or attitudes that were not constructive. How were non-facilitating behaviors handled? Was the method of dealing with those behaviors appropriate?

Conclusion: In any decision-making process there are social issues as well as scientific ones, personalities as well as ideas to consider. Developing an appropriate and socially acceptable way to deal with other people is an important part of becoming a good citizen.

Extensions:

1) Since the formation of the planet, Earth's systems have been constantly evolving and continue to do so. The locations of the continents have changed over time and the amount of land exposed has also fluctuated. What evidence has been found to promote this belief? Select one continent or island country and trace its origin from the break-up of the supercontinent to its present location. Investigate how much land is currently above sea level. How much of this country will disappear if sea levels rise as projected?

[Some people should select coral islands in the South Pacific.]

2) Human communities will not be the only ones to suffer if sea level rises. Many wetlands are located along the coastal areas. Examine the functions of these wetlands and how they could be affected by the high sea levels. Investigate the diversity of life in these areas at present and create a fact sheet on the different species that could become extinct from these areas as a result of this change in their environment. Are there any species that will benefit from this alteration in land/sea levels? (The fact sheet should be similar to the example shown for the spotted owl.)

Teacher Background Information:

Mitchell, J. G. 1992. "Our Disappearing Wetlands." *National Geographic.* 182 (4) : 3 - 45.
An excellent article that documents the location of wetlands in various states around the nation. The author examines how the perspective on wetlands changed and some of the current attempts to save wetlands. A collection of superb photographs and illustrations enhance this article.

Titus, J. G. 1989. "Preparing for Climate Change." In *The Potential Effects of Global Climate Change on the U.S.* Smith, J. B. and Tirpak, D. (Editors.) Washington D.C.: U.S. E.P.A. 389 - 399.
This chapter reports on some of the decisions that face people concerning sea level rise, concerning water allocation, land use, development and education.

Barth, M. C. and Titus, J. G. (Eds). 1984. *Greenhouse Effect and Sea Level Rise: A Challenge for This Generation.* New York: Van Nostrand Reinhold.
An excellent insightful book that foretold many of the problems we now face with global climate change. Graphs and charts are good for overview of the range of problems associated with sea level rise.

References:

General —
Begley, S. with Cohn, B. 1986. "The Rising Tides." *Newsweek.* June 23, 65 - 66.

Fortner, R. W. 1992. "How High's the Water." *Science Activities.* 29 (1) : 31 - 33.

Good, J. W. c1988. *Greenhouse Warming and Sea Level Rise.* Extension/Sea Grant Program, College of Oceanography, Ocean Administration Building 104, Oregon State University, Corvallis, OR 97330-5503. (503) 754-3771.

Jacobson, J. L. 1989. "Swept Away." *Worldwatch.* January/February. 20 - 26.

Jones, C. B. 1989. *Sea Level Rise: Assessing the Scientific Debate.* Unpublished paper. Honolulu: Pacific Basin Development Council. March 1989.

Lemonick, M. D. 1987. "Shrinking Shores: Overdevelopment, Poor Planning, and Nature Take their Toll." *Time.* August 10. 38 - 47.

National Oceanic and Atmospheric Administration/National Ocean Service. 1988. *Sea Level Variations for the United States 1855 - 1986.* U.S . Department of Commerce. February.

National Oceanic and Atmospheric Administration/National Ocean Service. 1989. *Tide and Current Glossary.* U.S. Department of Commerce. October.

National Research Council. 1987. *Responding to changes in sea level: Engineering Implications.* Washington, D. C.: National Academy Press.

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Titus, J. G. 1987. *Greenhouse Effect, Sea Level Rise and Coastal Wetlands.* Washington D. C.: U.S. Environmental Protection Agency (EPA).

Titus, J. G. 1984. "Sea Level Rise and Wetlands Loss in the United States." *National Wetlands Newsletter.* September/October, 4 - 6.

Whalen, C. T. 1987. *Control Leveling.* U.S. Department of Commerce, NOAA/ National Ocean Service. January.

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HOW DO GREENHOUSE GASES AFFECT HEAT ABSORPTION?

The Earth's climate depends on the amount of solar radiation received and the atmospheric abundance of clouds and greenhouse gases. The main greenhouse gases are carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, and ozone. Much of the high energy, short wavelength radiation from the sun passes through the Earth's atmosphere and hits the surface of the Earth. The energy that is not reflected off the surface is absorbed and re-radiated into the atmosphere, where much of it is absorbed by the greenhouse gases. This is known as the greenhouse effect (see Figure 1).

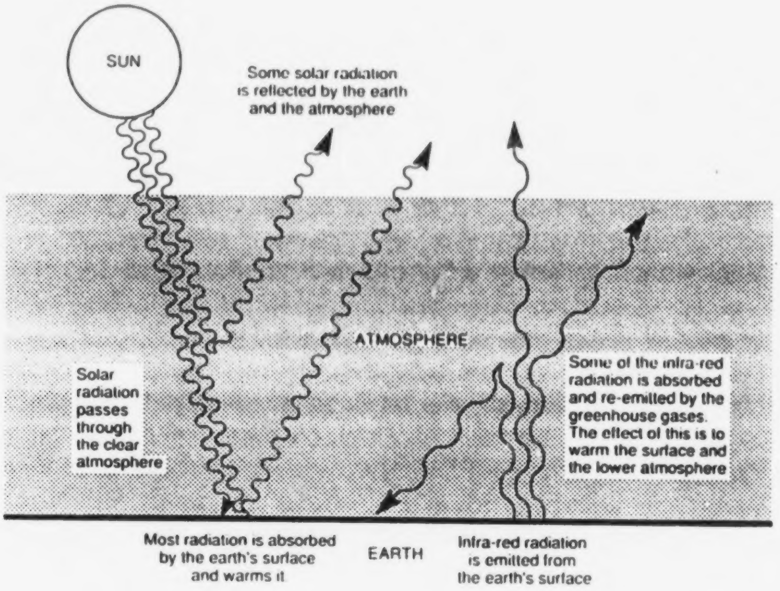
SUN
Some solar radiation is reflected by the earth and the atmosphere
ATMOSPHERE
Solar radiation passes through the clear atmosphere
Some of the infra-red radiation is absorbed and re-emitted by the greenhouse gases. The effect of this is to warm the surface and the lower atmosphere
Most radiation is absorbed by the earth's surface and warms it
EARTH
Infra-red radiation is emitted from the earth's surface

Figure 1. - **The Greenhouse Effect. (Source: Houghton, et al., *Climate Change: The IPCC Scientific Assessment*, 1990.)**

Nitrous oxide (N_2O) is a minor component of the atmosphere in terms of volume, but along with the other greenhouse gases it plays an important role in climate. In this activity you will simulate a portion of the greenhouse system using nitrous oxide. The concepts studied in this activity include: *greenhouse gases and greenhouse warming; the greenhouse effect; thermal equilibrium, and experimental variables.*

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with the support of The Ohio State University.

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Objectives: After completing this activity, each student will be able to:

1) describe the parts of the greenhouse effect; and
2) explain the effect of N_2O on the absorption of heat in the atmosphere.

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3 and 4, however the following ESUs are covered in the Extensions — 5, 6 and 7. Refer to the Framework for ESE for a full explanation of each ESU.

Materials: 2 clear, empty, 1-liter plastic pop bottles; cream whipper with one N_2O cartridge; 2 thermometers; infrared radiation source; two #4 rubber stoppers with one hole in each; 2 sheets of white paper; transparent or masking tape; parafilm or stopper grease; thin book, sponge or piece of wood; glycerine or other lubricant; graph paper; a meterstick.

Procedure:

1) Before the activity begins, the apparatus should be assembled by the teacher. Lubricate the bottom one-third of each thermometer with glycerine or other lubricant. Hold one of the thermometers with several layers of paper towels and gently push the thermometer through the hole in one of the rubber stoppers. Push until about 10 cm of the thermometer has passed through the other end of the stopper. **CAUTION: DO NOT FORCE THE THERMOMETER THROUGH THE HOLE. THE THERMOMETER MAY BREAK AND CAUSE INJURIES.** Make sure that you push the bulb end of the thermometer through and that you are pushing toward the small end of the stopper. Repeat with the other thermometer and rubber stopper.

[STRESS SAFETY: STUDENTS SHOULD WEAR GOGGLES.]

2) Wipe off the excess glycerine and then tape a small piece of white paper over one side of the bulb of each thermometer. The purpose of this paper is to shield the bulbs from the heat source. Make sure you affix the paper so that you can read the scale.

3) Place 1 N_2O cartridge in the empty cream whipper. Activate the cream whipper and "pour" the N_2O from the cartridge into one of the 1-liter bottles. Make sure to empty the whipper completely.

> [If you have available sources of CO_2 and/or CH_4, you may want to have two or more groups try this activity using one of these gases for comparison purposes.]

4) Stopper the bottle containing N_2O with one of the stopper/thermometer assemblies. Seal it with stopper grease or parafilm. Stopper the other 1-liter bottle in the same way. This bottle will have air in it. Label the first bottle "N_2O" and the second bottle "AIR".

5) Lay the two bottles down together on their sides and on a piece of white paper. Support the necks of the two bottles with a thin book, sponge, or piece of wood. Make sure that the pieces of paper you taped to the bulbs of the thermometers are on top and will shield the bulbs from the infrared heat source. Make sure that you can read the scale of each thermometer without moving the bottles.

6) Place the infrared heat source 0.5m above the 2 bottles. Make sure that both bottles are equidistant from the heat source.

7) On your own paper, record the temperatures in each bottle. Turn on the infrared source and record the temperatures in the two bottles at two minute intervals for a total of 16 minutes. (You should have 8 readings in addition to your original reading.)

8) At the end of 16 minutes, lower the infrared source to 0.25m above the bottles and continue to record the temperatures in the two bottles at two minute intervals for another 16 minutes. (You should now have 16 readings in addition to your original reading.)

9) After you have completed recording the temperatures for a total of 32 minutes, turn off the infrared heat source and feel the two bottles to see if you can detect a difference in temperature.

10) On the worksheet, use a line graph to show how the temperatures in the two bottles changed over time. Use a solid line for the temperatures from the bottle that contains air and a dashed line for the temperatures from the bottle that contains N_2O.

[You may want to have students calculate the slopes of both lines for comparison purposes.]

Evaluation:

1) What part of the greenhouse effect system does the infrared source represent?

[Heat from Earth's surface.]

2) What part of the greenhouse effect system is being represented by the 1-liter bottles?

[The atmosphere.]

3) Why was it necessary to shade the bulbs of the thermometers with pieces of white paper?

[To reduce the direct warming of the bulbs by the heat source.]

4) When the heating of the bottles was completed, which bottle felt warmer?

[The bottle containing N_2O.]

5) In which bottle did the temperature increase faster? Explain why.

[The bottle containing the N_2O. Because N_2O absorbs heat quicker than air.]

6) Was the rate of temperature increase for each bottle the same throughout the first 16 minutes?

[No.]

Explain why or why not. Keep in mind what the different parts of the apparatus represent.

[You may refer to the slopes of the lines. The temperature of the N_2O increased faster. Both lines flattened out as the system approached thermal equilibrium.]

7) How many times more heat energy was striking the two bottles after you lowered the infrared source to 0.25m?

[Four times — inverse square law.]

How did this affect the temperatures in the two bottles?

[They both increased.]

8) Was the rate of temperature increase for each bottle the same during the second 16 minutes? Explain why or why not. Keep in mind what the different parts of the apparatus represent.

[No. The temperature of the N_2O increased faster than the temperature of the air.]

9) Is the pattern of change of temperature in each bottle the same? Explain why or why not.

[Not exactly. The temperature of the N_2O increased faster than the temperature of the air. After a certain time, both lines flattened out.]

10) How would you know when the apparatus is in thermal equilibrium?

[The temperature in the bottles no longer increase.]

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11) Is Earth's atmosphere in thermal equilibrium at present? Explain.

[Global warming appears to be occurring, so the atmosphere is not in thermal equilibrium.]

12) Explain how the presence of N_2O and other "greenhouse" gases in the atmosphere affect the heating of the atmosphere from an infrared source.

[Greenhouse gases absorb heat, thereby trapping it in the atmosphere.]

13) Explain fully how this activity relates to the greenhouse effect in Earth's atmosphere.

[Answers should include descriptions of how increased amounts of greenhouse gases contribute to the warming of the atmosphere.]

14) In this activity, what variables help to determine the temperature of the gases in the bottles?

[Variables include, but are not restricted to: the strength of the heat source; the opacity of the plastic bottles; the distance between the bottles and the heat source; the concentrations of gases in the bottles; and the types of gases in the bottles.]

15) Choose one of the variables (Question 14) other than the distance between the infrared heat source and the bottles, and describe how you would repeat the activity to determine how that variable affects the temperature in the bottles.

[May have already done this with CO_2 and/or CH_4.
Answers will depend on the variable chosen.]

16) If human activity continues to add N_2O and other greenhouse gases to Earth's atmosphere through burning of fossil fuels, deforestation, and other human activities, predict how the average temperature of the atmosphere will change in the future.

[It will increase.]

There has been an increase in the amount of N_2O, CO_2 and other greenhouse gases in Earth's atmosphere in the last 150 years. This increase has been measured and recorded in a variety of ways. Much of it has been attributed to such human activities as deforestation and the burning of fossil fuels. The current rate of increase of CO_2 in the atmosphere is 0.5% per year. At this rate, computer models predict that the average global temperature could go up 3 - 5°C by the year 2050.

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[Consider these options when discussing the activity.

a) Have students explain why the initial temperatures in the two bottles were not the same. Discuss what would have to be done to make them the same.

b) What are the important aspects of the apparatus that determine at what temperature thermal equilibrium is reached — include discussion about the size of the bottle, the concentrations of gases in the bottles, and the opacity of the plastic.

c) How "real" is the lab set-up? There is a major difference between concentrations of greenhouse gases in the bottle(s) and in Earth's atmosphere. Discuss how an increase of just 2 or 3°C in the atmosphere could cause agricultural belts to migrate and cause potential famine or 'bring' hardships in some parts of the world.

d) What is the relative heat-absorbing effectiveness of each of the "greenhouse gases" you used in the activity? What is the relative abundance of these gases in the atmosphere?

e) Have the students create a concept map illustrating the process of heat absorption in the atmosphere and the consequences that it could produce on the various earth systems and human society.]

Extensions:

1) Earth is more than 4 billion years old. When did the atmosphere develop around the planet? Determine what role this played in the evolution of life. If the amount of greenhouse gases in the atmosphere continues to increase what impact would this have on all the life systems and the planet?

2) Venus is a planet whose orbit around the sun is closest to Earth's orbit. It has experienced greenhouse warming for many thousands of years and has a mean surface temperature of 480°C. How did the atmosphere form? Could this happen to Earth if the gas composition of the atmosphere alters? Support your answers with evidence.

3) The National Oceanic and Atmospheric Administration (NOAA) is one organization which monitors changes in the oceans and atmosphere of the planet. Many scientists, such as meteorologists, oceanographers, atmospheric scientists, etc., focus on different areas in their work. Select one of these scientists and investigate the type of training required for his/her career.

4) The demand for energy will continue to grow as the human population increases. To tackle the problem of the greenhouse effect, gases such as CO_2, CH_4

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and N_2O cannot continue to be pumped into the atmosphere. What alternative energy sources can be used to meet this increasing demand for energy? Select one of these energy sources and explain its advantages and disadvantages in relation to environmental impact. Also investigate how the public perceives this energy source. Support your answers with evidence.

Teacher Background Information:

Moore, P. and Hunt, G. 1990. *The Atlas of the Solar System.* New York: Crescent Books. (p. 104 - 105)
The section concerning the atmosphere of Venus documents how the atmosphere developed and how the greenhouse effect on the planet evolved. Diagrams of this process, while small, are an excellent representation and could easily be enlarged. They could also be placed on transparencies when enlarged. This would be a good way of allowing students to envision the process that may occur on Earth, should global warming (or an enhanced greenhouse effect) occur.

Matthews, S. W. 1990. "Under the Sun — Is Our World Warming?" *National Geographic.* 178 (4) : 66 - 99.
This is a superb article that deals with the complete topic of global warming. However, pages 72 - 77 concentrate on the influence of greenhouse gases on the process of global warming. Excellent illustrations and charts help to create an understandable account of the scientific processes involved.

Whitmore, S. C. 1991. "Global Climate Change and Agriculture — A Summary." In *Global Change Information Resources.* U.S. Department of Agriculture.
This summary contains an explanation of the greenhouse effect, a description of greenhouse gases, and the question "is the Earth warming?" A synopsis of the potential effects of climate warming on agriculture and forestry is also included.

References:

Boden, T. A., Kanciruk, P. and Farrell, M. P. 1990. *Trends '90 A Comparison of Data on Global Change.* Oak Ridge, TN: Carbon Dioxide Information Analysis Center. 266 pp.

Graedel, T. E. and Crutzen, P. J. 1993. *Atmospheric Change : An Earth System Perspective.* New York: W. H. Freeman and Company.
This recent publication examines the effect of atmospheric change on Earth and its subsystems. It contains relevant and up to date research.

Schlesinger, W. H. 1990. "Vegetation an unlikely answer." *Nature.* 348. December 20. p. 679.

Science Concepts, Inc. 1989. *Energy and the Greenhouse Effect.* Washington, D.C.: U.S. Council for Energy Awareness, 1776 I Street, N.W., Suite 400.

Smith, J. B. and Tirpak, D. 1989. *The Potential Effects of Global Climate Change on the United States.* Washington, D.C.: U.S. E.P.A. -230-05-89-050. 413 pp.

VIDEO:

A Co-Production of Maryland Public TV, Film Australia, Wiseman (UK), Electric Image (UK) in Association with Principal Film Company Ltd. (UK). 1990. *After the Warming.*

HELPFUL DEFINITIONS (VOCABULARY)

Greenhouse effect: "the trapping by atmospheric gases of outgoing infrared energy emitted by Earth. Part of the radiation absorbed by the atmosphere is returned to Earth's surface, causing it to warm" (Graedel and Crutzen, 1993, 430). Principal greenhouse gases are H_2O vapor, CO_2, O_3, CH_4, N_2, O, CF_2Cl_2, and $CFCl_3$.

Thermal equilibrium: balanced temperature regime achieved when the amount of heating leaving a system equals the amount entering.

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How much is the Global Energy Budget?

Figure 1. — The Global Energy Budget is regulated by Earth processes to sustain ideal global conditions. (Drawings by Ian Winton reprinted by permission of Grosset & Dunlap from *THE BIG GREEN BOOK* by Fred Pearce, Illustrations © 1991 by Ian Winton.)

A budget is a plan that shows how something enters and leaves a system and how much remains in a system. A household budget lists the amount of money that comes into the household (earned), the amount that goes out (spent), and the amount that stays in the household (savings). Budget plans can be used for things other than money. Systems on Earth are often described in terms of budgets.

The energy budget of the Earth involves incoming solar energy, outgoing amounts of energy from the atmosphere into space, the amount of energy that remains in the atmosphere, and how the energy flows from one place to another.

There are many different ways to represent the energy balance of the Earth. Figures 1, 2, and 4 are examples. The numbers used in these diagrams are approximations based upon the **solar constant**, which is a measure of the amount of solar radiation that reaches the upper part of the Earth's atmosphere. The solar constant is not truly a constant because the amount of energy that is radiated by the Sun varies slightly over an 11 year cycle and varies greatly over time spans of millions of years. For example, the Sun is believed to have been 25% to 30% fainter when the Solar System formed about 4.5 billion years ago than it is now. The amount of energy that reaches the Earth from the Sun is called **insolation.** Units of this energy are watts/sq. meter/second ($W/m^2/sec.$). You can think of it as the amount of energy absorbed every second by a pure black, square object that measures 1 meter on a side and is at the top of the atmosphere.

The concepts studied in this activity include: *solar energy; energy budget; greenhouse effect; solar cycle and cause-effect relationships.*

Objectives: After completing this activity, each student will be able to:

1) describe what happens to solar energy when it reaches the Earth;
2) describe how the energy budget of the Earth is balanced;
3) list some variables that affect the greenhouse effect; and
4) discuss how changes in the greenhouse effect can affect the temperature of a planet.

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3 and 6, however the following ESUs are covered in the Extensions — 1, 4 and 7. Refer to the Framework for ESE for a full explanation of each ESU.

Materials: pen or pencil.

Procedure:
Use Figure 1 to answer the following questions.

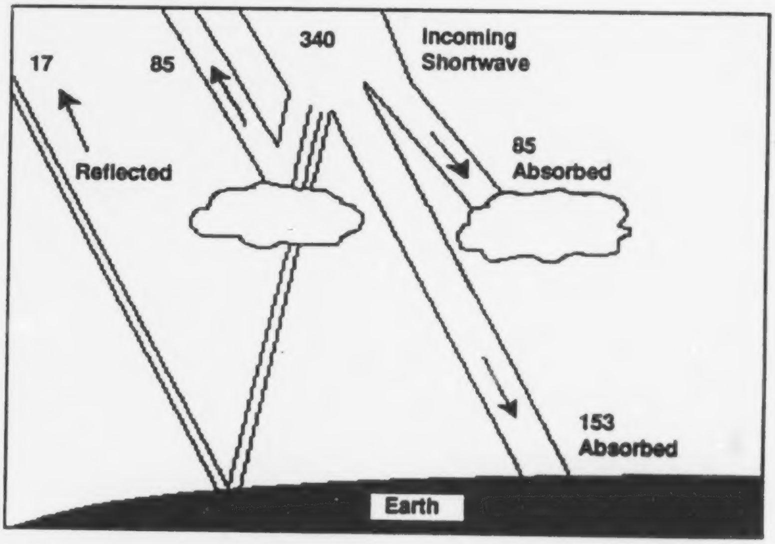

Figure 1. - Insolation. Numbers represent energy in Watts/sq. meter/sec. (Source: "Adapted from "The Changing Climate," by Stephen H. Schneider. Copyright © 1989 by *Scientific American*, Inc. All rights reserved. The illustration may not be reproduced without written permission from Scientific American, Inc., 415 Madison Avenue, New York, New York 10017.")

1) How much shortwave energy comes in from the Sun as measured at the top of the atmosphere?

[340 W/m^2/sec.]

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2) What is the total amount of shortwave radiation that is reflected by the atmosphere (mainly clouds) and the Earth's surface (land, ice, and oceans)?

[102 W/m^2/sec.]

3) What happens to the energy that is not reflected directly back into space?

[It is absorbed by clouds and Earth's surface.]

How much energy is this?

[238 W/m^2/sec.]

This is the amount of energy that enters the Earth's energy budget from space.

Use Figure 2 to help you answer questions 4 and 5:

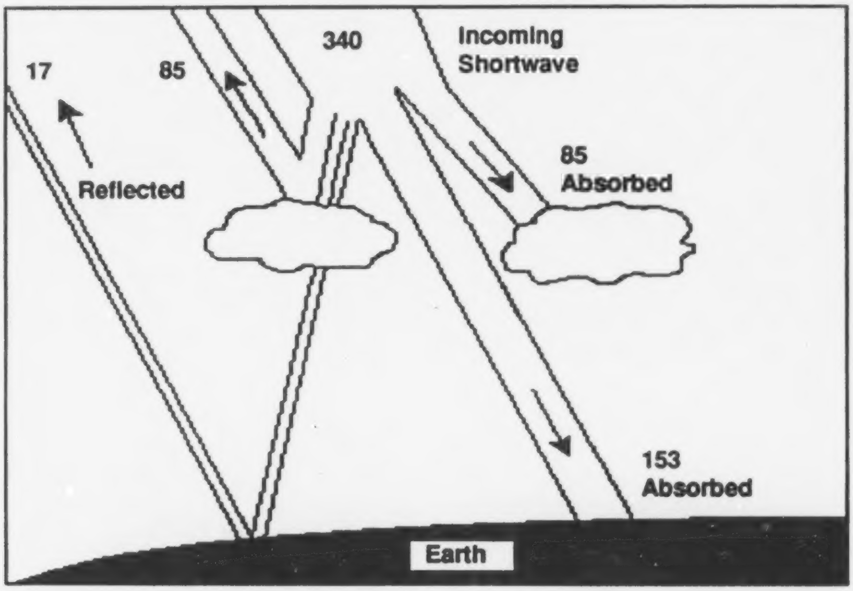

Figure 2. - **Outgoing Energy. Numbers represent energy in Watts/sq. meter/sec. (Source: "Adapted from "The Changing Climate," by Stephen H. Schneider. Copyright © 1989 by *Scientific American*, Inc. All rights reserved. The illustration may not be reproduced without written permission from Scientific American, Inc., 415 Madison Avenue, New York, New York 10017.")**

4) How much total energy is given off by the Earth's surface? (Do not consider reflection.)

[453 W/m^2/sec.]

The energy coming from the Earth's surface is in the form of infrared radiation. It results from the heat required to evaporate water (Atmospheric Processes) and radiation from the Earth in the forms of geothermal heat and heat energy from absorbed insolation that is re-radiated.

Some of this infrared energy from the surface is trapped in the atmosphere by CO_2, H_2O vapor, and O_3, and some passes through into space. Energy that has wavelengths ranging from 7 to 17 micrometers (μm) is not absorbed well by CO_2, H_2O vapor, and O_3, so it passes through the atmosphere and into space. This is known as an atmosphere "window." In Figure 3, this is represented by the open space beneath the curve. The curve on the diagram represents the maximum amount of energy that could be absorbed by the atmosphere by different gases and wavelengths of radiation. The empty space below the curve represents amounts of energy that are not now being absorbed but could be if the amounts of certain gases (especially CH_4) were to increase.

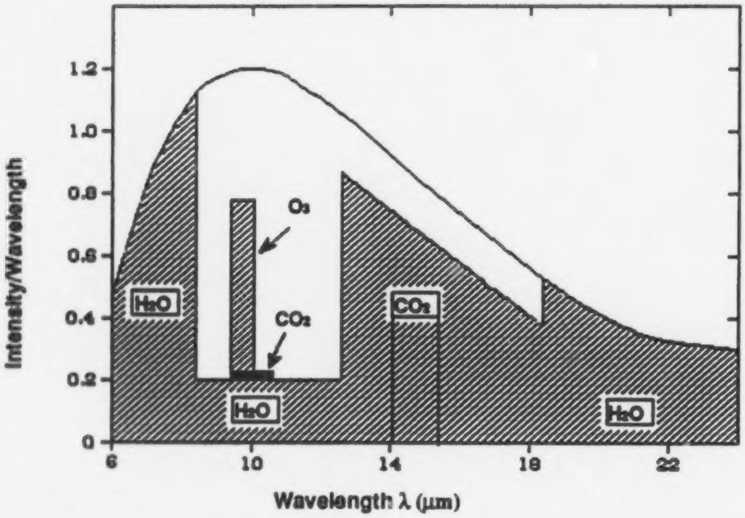

Figure 3. - **Atmospheric Absorption of Energy. The white area represents the atmosphere's ability to absorb extra gases and energy. CO_2 and H_2O simultaneously absorb energy at wavelength 14 μm.**
(Source: Abrahamson, *The Challenge of Global Warming*, 1989.)

Testimony given in a joint hearing before the Subcommittees on Environmental Protection and Hazardous Wastes and Toxic Substances of the Committee on Environment and Public Works, U.S. Senate, One-hundredth Congress, first session, 28 January 1987.
The original publication of this paper provided illustrations that have not been included here. These illustrations depicted the estimated variation of atmospheric methane concentration (Stauffer et al., 1985) and the trend in mean annual ozone concentration at Rugen, German Democratic Republic (after Warmbt, 1979.)

Methane (CH_4) is very good at absorbing energy at wavelengths of 7 to 17 μm. An increase in CH_4 in the atmosphere can act to "close" or "dirty" this window, so more heat energy could be trapped in the atmosphere and less radiated into space.

5) Explain how an increased amount of CH_4 in the Earth's atmosphere would influence the greenhouse effect and global warming.

[More heat energy would be absorbed, so the atmosphere would become warmer.]

6) From Figure 3, what gas absorbs energy at almost all wavelengths?

[H_2O vapor.]

7) From Figure 2, how much infrared energy is radiated by the atmosphere into space?

[238 $W/m^2/sec$.]

This is the amount of energy that leaves the Earth's energy budget.

Use Figure 4 to answer these questions. Figure 4 is Figures 1 and 2 put together.

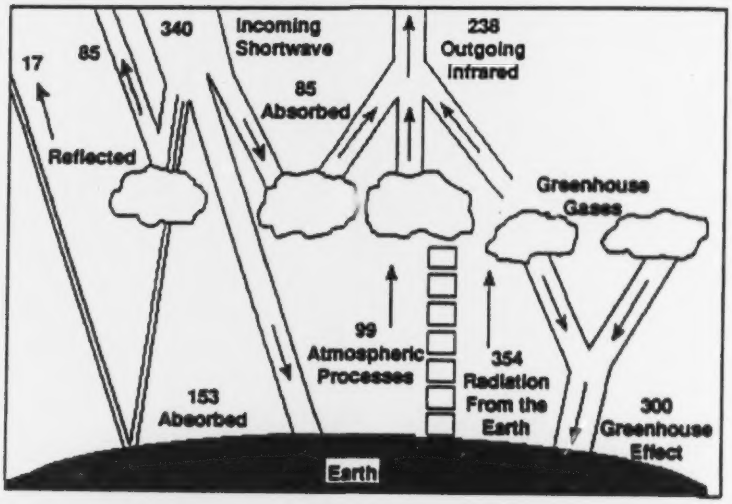
17
85
340
Incoming Shortwave
238
Outgoing Infrared
85
Absorbed
Reflected
Greenhouse Gases
99
Atmospheric Processes
354
Radiation From the Earth
153
Absorbed
300
Greenhouse Effect
Earth

Figure 4. - Earth's Energy Budget. Numbers represent energy in Watts/sq. meter/sec. (Source: "Adapted from "The Changing Climate," by Stephen H. Schneider. Copyright © 1989 by *Scientific American*, Inc. All rights reserved. The illustration may not be reproduced without written permission from Scientific American, Inc., 415 Madison Avenue, New York, New York 10017.")

8) How does the amount of energy entering the Earth's energy budget from space (Question 3) compare with the amount of energy leaving the Earth's energy budget into space (Question 7)?

[The amounts of energy are the same.]

9) Over long periods of time (several years), is the amount of energy entering and leaving the Earth's climate system balanced? Explain.

[Yes. The amount that enters and the amount that leaves are the same.]

10) If nothing changes within the system, would you expect the average temperature of the Earth to stay the same? Explain.

[Yes. The amount of energy that stays in the atmosphere would remain the same.]

11) How much energy is absorbed by the Earth's surface (land, ice, and oceans)?

[153 $W/m^2/sec.$]

12) What is the difference between this amount of energy (Question 11) and the total amount of energy radiated by the Earth's surface (Question 4)?

[300 $W/m^2/sec.$]

This is the energy returned to the Earth (or "trapped" by the atmosphere), which is responsible for heating the atmosphere to an average temperature of 15°C. This is known as the greenhouse effect. The heat is captured and re-radiated back to Earth by clouds, H_2O vapor, O_3, CH_4, N_2O, NO_x, and CFC's (chlorofluorocarbons). Without the greenhouse effect part of the climate system, the Earth's surface would be about 33°C cooler than it is now. It would be about the same as the surface temperature of the Moon (about -18°C.).

13) Why would an Earth with no greenhouse effect have a temperature about the same as the Moon's?

[The Moon has no atmosphere and it is about the same distance from the Sun as Earth is from the Sun.]

14) Explain what would happen to the Earth's energy budget and the greenhouse effect if the amount of insolation increased.

[The amount of energy entering the budget would increase and the amount absorbed (greenhouse effect) would increase.]

15) Explain what would happen to the temperature of the atmosphere if the amount of greenhouse gases was to increase.

[The temperature would probably increase.]

As the energy budget of the Earth gets larger, more energy is in the atmosphere. This can lead not only to higher temperatures, but also may affect the weather. Storms may become more severe when more energy is available in the atmosphere to power them.

What could happen to the temperature of a planet's atmosphere if the amount of greenhouse gases, particularly CO_2, were to change can be illustrated by what some scientists believe may have happened to the atmospheres of Venus and Mars. On Venus, there is a large amount of CO_2 in the atmosphere. The greenhouse effect on Venus is much stronger than on Earth. The surface temperature (460°C) of Venus is hot enough to melt lead.

On Mars, there is very little CO_2 in the atmosphere. Mars is much colder than Earth. Some scientists believe that there was more CO_2 in the atmosphere of Mars in the past, so it may have been warmer in the past. To find out more about this, see the activity entitled "The Goldilocks Problem."

In Question 14, you thought about the implications of increasing insolation on the greenhouse effect. As was mentioned in the introduction, the amount of energy being radiated by the Sun has not always been the same as it is now. The changing activity of the Sun can be illustrated by looking at how the number of sunspots has changed over time.

Figure 5 is a graph of the number of sunspots observed on the surface of the Sun from the year 1610 to 1988. In general, a larger number of sunspots in a year reflects greater solar activity. The more active the Sun is, the more energy it radiates.

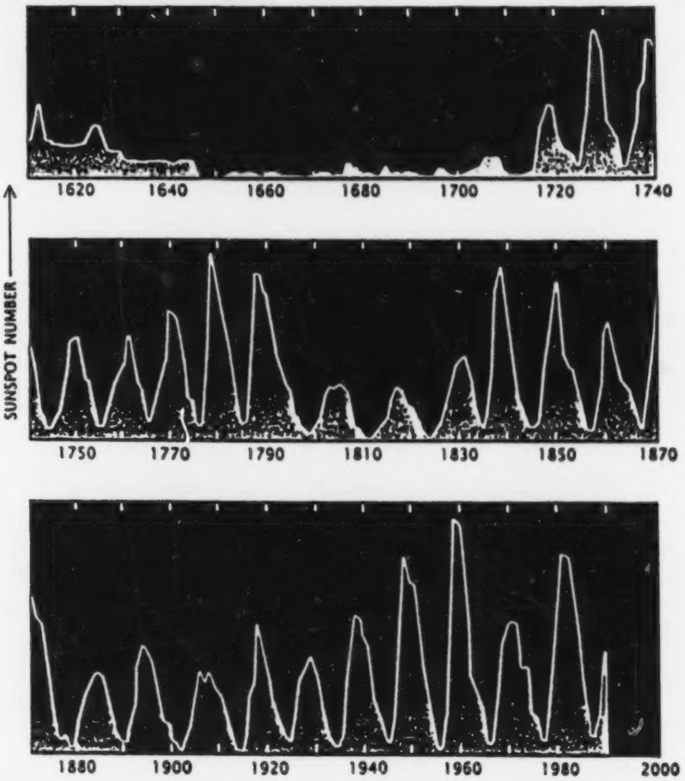

Figure 5. - Numbers of Sunspots. ("From: "The Variable Sun," by Peter V. Foukal. Copyright © 1990 by *Scientific American*, Inc. All rights reserved. The illustration may not be reporduced without written permission from Scientific American, Inc., 415 Madson Avenue, New York, New York 10017.")

16) The peaks on the graph represent times when there were sunspot maximums. According to the graph, what two years had the greatest number of sunspots?

[1780 and 1960 had the greatest number of sunspots.]

17) Was the amount of energy being given off by the Sun during these two times (Question 16) greater than normal or less than normal? Explain.

[The amount of energy was greater than normal. In general, the greater the number of sunspots, the more active the sun.]

18) Estimate the average number of years that occur between one sunspot minimum and the next one. This amount of time is known as the **solar cycle.**

[About 22 years.]

19) During what 70 year time period was sunspot activity very low?

[Activity was very low between 1645 and 1715.]

This time period has been called the Maunder minimum because of the low numbers of sunspots. On Earth, it was a time of unusually cold weather. Glaciers across the Earth, especially in the Northern Hemisphere, advanced. This time of advancing glaciers has been called "The Little Ice Age."

20) Explain how the Maunder minimum and the Little Ice Age may be related events.

[Lower numbers of sunspots indicate lower level of solar activity. Less energy may have entered Earth's energy budget at that time.]

Cycles of solar activity have an important, yet poorly understood, effect on the temperature of the Earth. Sunspot activity in 1990 was among the highest on record.

21) Discuss how a large number of sunspots in 1990 might affect scientists doing research to detect global warming.

[Temperature increases caused by increased amounts of greenhouse gases may be hidden by increased temperature caused by a higher level of solar activity.]

21) Using all the information that you have learned in this activity, produce a concept map that illustrates the different influences on the global energy budget. The map should also include areas that the energy impacts.

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Extensions:

1) Earth is a planet with subsystems (water, land, ice, air and life) that have evolved and developed over millions of years. In the last thousand years and particularly in the last few centuries humans have greatly altered many aspects of Earth. Would a change in the global energy budget impact all of these systems? How? How would this change impact the human species? Support your answer with evidence.

2) Examine the careers of your parents/guardians. Describe what will happen to their careers should the global energy budget change.

3) The year is 2050. The global energy budget has been altered by human activity. As you look out of the window in your specially constructed home, a tremendous storm is sweeping across the countryside. You begin to remember the year 1990 and reminisce on how different the environment was at that period. Describe the local and global environments of 2050 and how they differ from that of 1990.

Teacher Background Information:

Matthews, S. W. 1990. "Under the Sun — Is Our World Warming?" *National Geographic.* 178 (4) : 66 - 99.
This is a superb article that deals with the complete topic of global warming. However, pages 85 - 91 concentrate on the influence of sunspots and the quality of radiation emitted by the Sun. Excellent photographs of the Sun's surface are also included in this article.

References:

Abrahamson, D. E. (Ed.) 1989. *The Challenge of Global Warming.* Washington, D.C.: Island Press.

Foukal, P. V. 1990. "The Variable Sun." *Scientific American.* 262 (2) : 34 - 41.

Graedel, T. E. and Crutzen, P. J. 1993. *Atmospheric Change : An Earth System Perspective.* New York: W. H. Freeman and Company.
This recent publication examines the effect of atmospheric change on Earth and its subsystems. It contains relevant and up to date research.

Schneider, S. H. 1989. *Global Warming. Are We Entering the Greenhouse Century?* San Francisco: Sierra Club Books.

Schneider, S. H. 1989. "The Changing Climate." *Scientific American.* 261 (3) : 70 - 79.

Winton, I. 1991. In Pearce, F. *The Big Green Book*. New York: Grosset and Dunlap, Inc.

HELPFUL DEFINITIONS (VOCABULARY)

Solar constant: the relatively constant amount of solar energy that reaches the top of Earth's atmosphere.

Geothermal heat: the heat that originates beneath the surface of Earth. It is produced through the decay of radioactive elements and through mantle convection.

Greenhouse effect: "the trapping by atmospheric gases of outgoing infrared energy emitted by Earth. Part of the radiation absorbed by the atmosphere is returned to Earth's surface, causing it to warm" (Graedel and Crutzen, 1993, 430). Principal greenhouse gases are H_2O vapor, CO_2, O_3, CH_4, N_2, O, CF_2Cl_2, and $CFCl_3$.

Solar cycle: the natural variation of sunspot activity. There are about 22 years between times of maximum/minimum number of sunspots.

Insolation: the amount of energy that reaches Earth from the sun.

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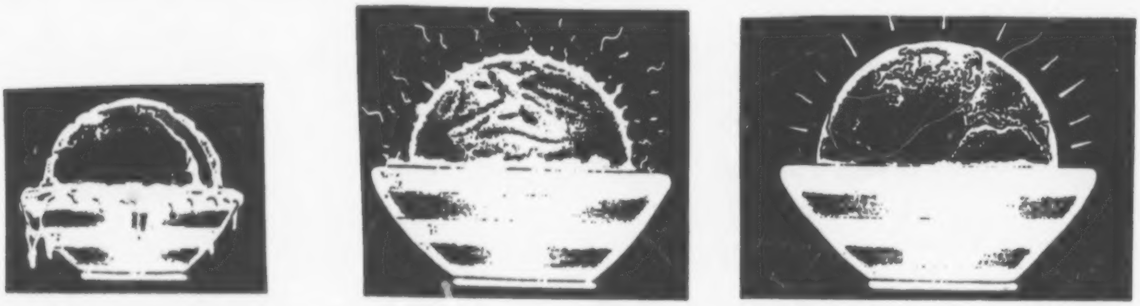
THE “GOLDILOCKS” PROBLEM

OR:

WHY IS THERE LIFE ONLY ON EARTH (AS FAR AS WE KNOW)?

The Earth is unusual, as far as the planets are concerned, in that water exists either as a solid, a liquid or a gas on its surface. The distribution of water in these different states varies with changes in altitude and latitude. Average global temperature is about 15°C, so most of the water on Earth is liquid.

The vast majority of life on Earth either lives in this liquid water and/or is largely composed of liquid water. The presence of water on Earth and the temperature of the Earth's surface are two of the major reasons why life as we know it exists here.



Mars is too cold..... **Venus is too hot.....** **but Earth is just right for life to flourish.**

(Drawings by Ian Winton reprinted by permission of Grosset & Dunlap from *THE BIG GREEN BOOK* by Fred Pearce, Illustrations © 1991 by Ian Winton.)

How is the temperature of the Earth's surface and the atmosphere just above it controlled? How is human activity influencing these controls? Over long periods of time will the activities of humans have an impact on the climate of the Earth? Can the atmospheres of Venus and Mars be used as examples of what might be happening to the atmosphere of Earth? The concepts studied in this activity include: *the Continuously Habitable Zone; greenhouse effect; chemical cycles; modeling and the Goldilocks Problem.*

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

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Objectives: After completing this activity, each student will be able to:

1) explain how temperature affects the physical state of water (Activity A).
2) describe how the physical state of water is related to life on Earth (Activity A).
3) explain how the distance of the Earth from the sun affects the temperature of Earth's atmosphere (Activity A).
4) discuss how the greenhouse effect helps to determine the temperature of planets (Activity B).
5) speculate on how the temperatures of Venus and Mars could have been different in the past and what effect this could have had on life on those planets (Activity C).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2, 3 and 6, however the following ESUs are covered in the Extensions — 1, 4, 5 and 7.

Materials: pen or pencil; photos of portions of the surfaces of Mars and Earth.

Activity A: What is the Continuously Habitable Zone (CHZ)?

Water will exist as either solid, liquid, or gas depending upon the pressure exerted on it and its temperature. This relationship is shown in the water phase diagram (Figure 1).

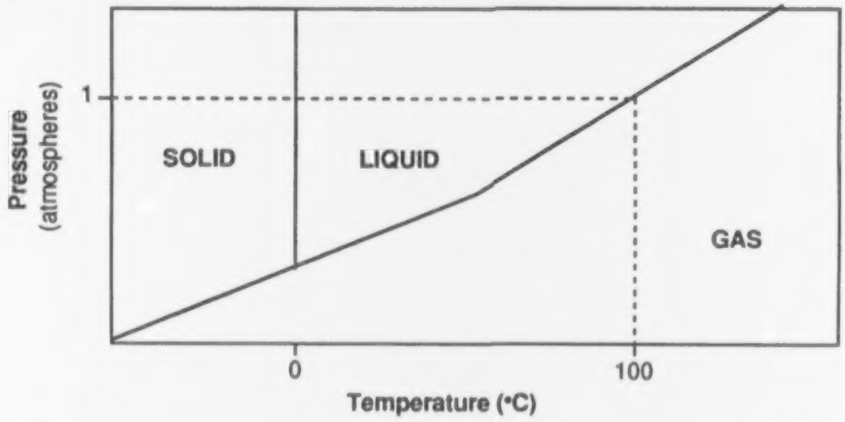

Figure 1. - Water Phase Diagram

Procedure:

Use Figure 1 and the information cited to answer questions 1 - 10.

1) Is 100°C the only temperature at which liquid water will boil into water vapor? (See Figure 1.) Explain.

[No. Water will boil at other temperatures depending on the pressure.]

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Using a computer model program, Hart (1988) at NASA predicted what would happen to the temperature of Earth's atmosphere if Earth was moved closer in its orbit to the sun. He also predicted what would happen if Earth was moved farther away from the sun. From his model, which kept the amount of CO_2 in the atmosphere constant over time, Hart predicted that moving the Earth 5% closer to the sun (to a distance of 0.95 astronomical units) would cause the average global temperature to increase to over 100°C.

2) What is the average global temperature at the present time?

[Approximately 15°C.]

3) Assume that Earth's atmosphere would not change significantly except for temperature, and use Figure 1 to help you predict what would happen to the water in the oceans if Earth was moved at least 5% closer to the sun.

[The water would all evaporate.]

4) Predict how this would likely affect life as we know it on Earth.

[Life as we know it would probably end.]

Moving the Earth just 1% farther from the sun (to a distance of 1.01 astronomical units) would, according to Hart's model, cause the average global temperature to drop to 0°C. (Again, the amount of CO_2 in the atmosphere is kept constant in Hart's model.)

5) Use Figure 1 to help you predict what would happen to the liquid water on Earth's surface if Earth was moved 1% farther from the sun.

[All the liquid water would freeze.]

6) Predict how this would likely affect life as we know it on Earth.

[If the atmosphere did not significantly change, life as we know it would probably end.]

As a result of the findings of the model, Hart has called the area between 0.95 and 1.01 astronomical units from the sun the **Continuously Habitable Zone (CHZ)** (See Figure 2).

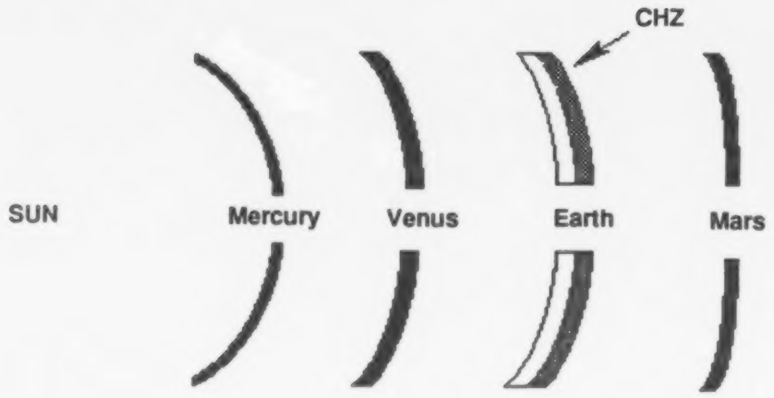

Figure 2. - The location of four planets in relation to the sun and the Continuously Habitable Zone (CHZ).

Based upon Hart's simple model, it seems that this very narrow band of distance from the sun is the only position that provides just the right conditions for life on Earth as we know it.

7) Discuss the implications of Earth being "lucky" enough to be "just the right" distance from the Sun to support life.

> [Answers will vary — this is a good time to discuss that life on Earth affects the atmosphere.]

8) If there are other stars in our galaxy that have planets, how likely do you think it is that any of them are "just the right" distance from their star to support life similar to life on Earth?

> [Probably not.]

Hart's model used the distance from Earth to the sun as the only variable that controls the temperature of Earth's surface.

9) List other variables that may help to control the temperature of the surface of Earth.

> [Answers should include: the amount of reflection from the sun; the characteristics of Earth's atmosphere; and changing albedo of Earth's surface.]

10) Since Hart's model uses the distance from the sun to Earth as the only variable in determining temperature, how accurate is the model likely to be? Explain.

> [It is unlikely to be very accurate. Earth's system is much more complex than the model.]

Activity B: How does the Greenhouse Effect modify Earth's temperature?

Computers have become increasingly fast and powerful over the last several years. With this greater speed and memory, computer models have become more complicated and can now include many different variables in a problem. These models, no matter how sophisticated, are still only as good as the data that scientists use to begin the program. As the quality and amount of data that the computer program can use increases, so will the ability of the computer models to predict climate in the future.

What variables really do help determine the temperature of Earth's surface? One thing, as we have discovered in Activity A, is the distance from the sun. Another is the amount of energy the sun radiates over time. This is known as the sun's **luminosity.** It is believed that the sun is 25% to 30% brighter now than when the solar system was formed. The sun's luminosity is increasing at a rate of about 1% every 100 million years. This may be insignificant over the lifetime of a human, but it represents a significant increase when one considers the great expanse of time since the solar system formed.

The surface of Earth is not the same everywhere. There is liquid water, land, and ice distributed over different parts of the surface, and this distribution has changed over time. The amounts of ice on Earth's surface have differed throughout time, and the continents have drifted, changed in size and have had differing amounts of land exposed above sea level. Each of these types of surfaces absorbs and reflects different amounts of energy from the sun. As the distributions of these surfaces have changed , so has the amount of energy absorbed and reflected by these surfaces. The amount of energy reflected by all Earth's surfaces is known as the **albedo**.

Clouds also affect the overall albedo of Earth. Clouds reflect energy from the sun back into space. Clouds are also good at trapping heat that is already in the atmosphere. The overall effect of clouds on the temperature of the atmosphere is mixed, and is poorly understood at this time. By comparing the temperatures of cloudy nights with those of clear nights that occur a few days apart one gets an idea of how clouds can affect temperature. Cloudy nights will generally be warmer because the clouds prevent some of the heat from the Earth from escaping into space. Other variables or factors, however, can influence the temperature of the atmosphere, so this relationship may not always be true. An important factor in determining the temperature of Earth's surface is the greenhouse effect.

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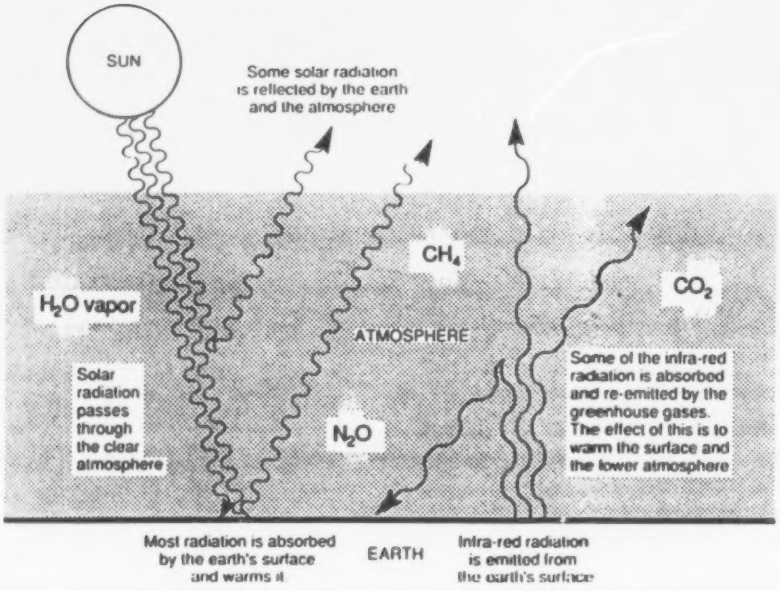
SUN
Some solar radiation is reflected by the earth and the atmosphere
H_2O vapor
CH_4
CO_2
ATMOSPHERE
Solar radiation passes through the clear atmosphere
N_2O
Some of the infra-red radiation is absorbed and re-emitted by the greenhouse gases. The effect of this is to warm the surface and the lower atmosphere
Most radiation is absorbed by the earth's surface and warms it
EARTH
Infra-red radiation is emitted from the earth's surface

Figure 3. - The Greenhouse Effect. (Source: Adapted from Houghton, et al., *Climate Change: The IPCC Scientific Assessment*, 1990.)

Kasting, et al., (1988) have written a computer model to predict the temperature changes that might occur when there are changes in the greenhouse effect.

Materials: pen or pencil; photos of portions of the surfaces of Mars and Earth.

Procedure:

1) Look at Figure 3 and write down the names of the principal gases that are involved in the greenhouse effect.

[CO_2, H_2O vapor, CH_4, N_2O.]

Each of these gases absorbs heat in the atmosphere and helps to determine the temperature of the atmosphere.

2) How could the amounts of these gases in the atmosphere change over time?

{Human activity — burning of fossil fuels, deforestation.]

3) Have the amounts of any of these gases in the atmosphere changed over the last 150 years? Explain.

[Yes. Use data from *Trends '90* reference.]

Kasting, et al., believe that carbon dioxide (CO_2) is the major greenhouse gas and that changes in the amount of CO_2 in the atmosphere control the temperature of a

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planet (as long as it has an atmosphere). They propose that whatever controls the amount of CO_2 in the atmosphere will indirectly control temperature. This is the basis for their computer model. They believe that it is the carbonate-silicate cycle (Figure 4) that controls the cycling of CO_2 on Earth.

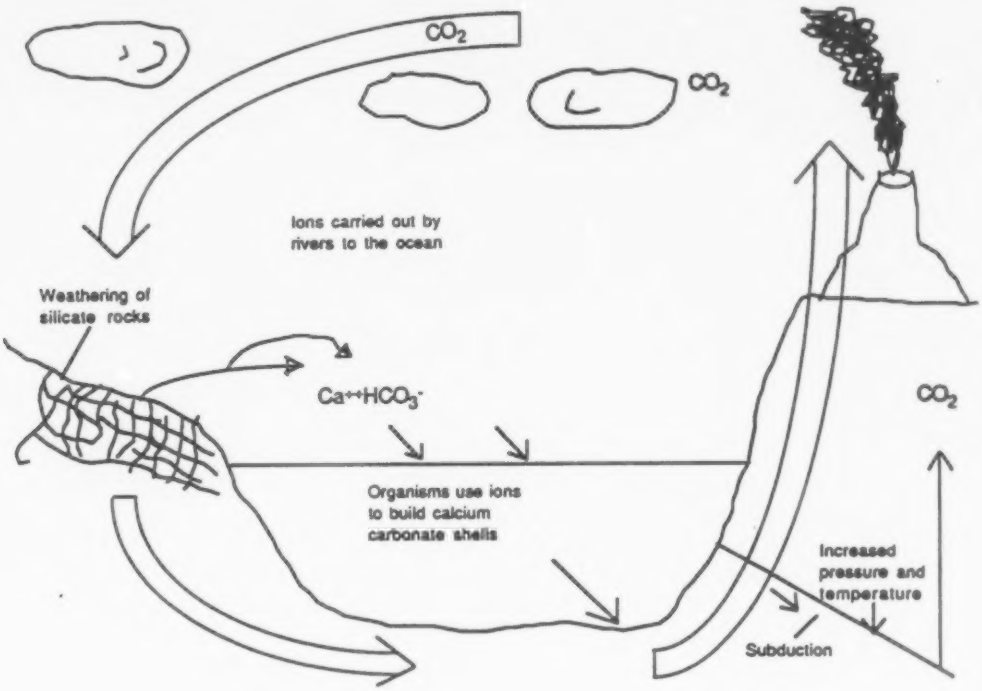
CO_2
CO_2
Ions carried out by rivers to the ocean
Weathering of silicate rocks
$Ca^{++}HCO_3^-$
CO_2
Organisms use ions to build calcium carbonate shells
Increased pressure and temperature
Subduction

Figure 4. - CO_3 — SIO_3 Cycle

4) According to Figure 4, how does CO_2 get into the atmosphere?

[CO_2 enters the atmosphere through volcanic activity.]

How is it removed from the atmosphere?

[CO_2 is removed from the atmosphere through precipitation and the weathering of silicate rocks.]

How are processes in the ocean involved?

[The oceans dissolve CO_2 and marine organisms build shells.]

5) When the amount of CO_2 in the atmosphere increases, what happens to the temperature of the atmosphere?

[The temperatures increases.]

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6) How would this affect the amount of evaporation of water from the ocean?

[Evaporation would increase.]

This would likely increase the cloudiness of the atmosphere and the amount of precipitation, although this effect would not occur in the same way on all parts of Earth.

7) How might increased precipitation affect the amount of CO_2 removed from the air?

[Increased precipitation could increase the amount of CO_2 removed.]

What change in the temperature of the atmosphere might result?

[The temperature could decrease.]

This could counteract the effect of the increase of CO_2 in the atmosphere. A decrease in the present amount of CO_2 in the atmosphere would likely cause a cooling of Earth.

8) How would this (the cooling) affect the amount of evaporation of water from the ocean?

[Evaporation would probably decrease.]

9) How might this affect the amount of CO_2 being removed from the atmosphere?

[The amount of CO_2 removed would decrease.]

10) Over long periods of time, the amount of CO_2 entering the atmosphere from volcanic eruptions would apparently not vary, so over time, how would the amount of CO_2 in the atmosphere change?

[The amount of CO_2 would stay relatively constant.]

Overall, the carbonate-silicate cycle, as described by Kasting et al., counteracts changes in the CO_2 content of the atmosphere, so the amount of CO_2 remains balanced. It takes a long time — in human terms — for CO_2 to cycle through this system: approximately 500,000 years.

11) According to this model, will an increase in CO_2 in the atmosphere because of the burning of fossil fuels and other human activities have a long-range effect on the temperature of Earth?

[No. The carbonate-silicate cycle will likely counteract any temperature changes.]

Is it likely to have a short term effect? Explain.

[Yes. It takes thousands of years for the carbonate-silicate cycle to respond.]

12) How good do you think this model is?

[This model is better than the other model but the real Earth system is much more complex.]

What sources of atmospheric CO_2 are not included in the model?

[The burning of fossil fuels, the decomposition of organic material, and deforestation.]

13) What is another way that CO_2 is removed from the atmosphere other than the ones used in the model?

[Photosynthesis.]

The role of life in the carbonate-silicate cycle is ignored in this model, because we are interested in comparing Earth with Venus and Mars, where life as we know it does not exist. Many people believe that the effect of life on the cycle — through photosynthesis, respiration and decomposition — is the most important part of it.

14) What greenhouse gases are not included in the model? (See Figure 3.)

[CH_4, N_2O, CFCs, H_2O vapor.]

What are some of the sources of these gases?

[The decomposition of organic material, the burning of biomass, and human activity.]

How might these gases be removed from the atmosphere?

[The gases may dissolve in the ocean or combine chemically with other substances in the atmosphere.]

15) How good do you think this model is in predicting how the temperature on Earth may change over time?

[The model is not very good for predicting how much or how fast temperature may change.]

270

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16) Why is it extremely difficult to accurately model Earth systems like global climate which are influenced by the greenhouse effect?

[Earth systems are very complex. Our knowledge of Earth systems is very limited.]

Even though the sun was 25% - 30% fainter a few billion years ago than it is now, Earth was warm at that time. We know this because there are rocks that formed at that time that could only have been formed in liquid water. The first primitive forms of life also began about 3.5 billion years ago when the Sun was fainter. It was possible for Earth to be warm at that time — even though the Sun was fainter — because there were larger concentrations of greenhouse gases, especially CO_2, in the atmosphere.

Activity C: What is the Goldilocks Problem?

Venus and Mars are the two planets whose orbits around the sun are closest to Earth's orbit. For many years, scientists, authors, and many others have speculated about the existence of life on these two closest neighbors of Earth. The distance between Venus and the sun is less than the distance between Earth and the Sun. Venus is at an average distance of 0.72 astronomical units from the Sun.

1) Does this put it within Hall's CHZ? (See Figure 2.)

[No.]

2) Mars is, on average, 1.52 astronomical units from the sun. Is Mars within Hall's CHZ?

[No.]

Venus is about the same size as Earth. It has sufficient gravity to have an atmosphere, although this atmosphere is much denser than Earth's. It is composed largely of CO_2 and it also has thick clouds composed mainly of droplets of sulfuric acid. These clouds reflect about 80% of the energy that Venus receives from the Sun. Therefore, even though Venus is much closer to the Sun than Earth, its surface receives only about 90% of the solar energy that Earth receives at its surface. The average temperature of the surface of Venus is 480°C, hot enough to melt lead.

3) According to Hall's model, how likely is it that life as we know it exists on Venus or Mars? Explain.

[Not very likely. Because there is no liquid water present on either planet.]

4) If Venus receives only 90% as much solar energy as Earth at its surface, why is Venus so much hotter?

[The high temperature on Venus is the result of what has been called a runaway greenhouse effect.]

There is a very strong greenhouse effect on Venus.

5) In Activity B, you looked at the carbonate-silicate cycle and how it might control the amount of CO_2 in the atmosphere. What parts of the carbonate-silicate cycle are missing on Venus?

[Ocean processes, volcanic activity.]

6) There may have been water on Venus early in the history of the solar system. If there was, how could that have affected the amount of CO_2 in its atmosphere?

[The amount of CO_2 could have been less because of an active carbonate-silicate cycle.]

Explain how the temperature of Venus may have been different at that time than it is now (remember the sun was fainter then).

[The temperature may have been lower if there were less CO_2 in the atmosphere.]

Speculate on how this may have affected the possibility of the presence of life on Venus at that time.

[With liquid water present, life may have been possible.]

Kasting's, et al., model suggests that a planet the size of Earth with an active carbonate-silicate cycle (Figure 4) that can control the amount of CO_2 in the atmosphere might be able to support some kind of life as far as 1.5 astronomical units from the Sun. This would expand Hall's CHZ considerably.

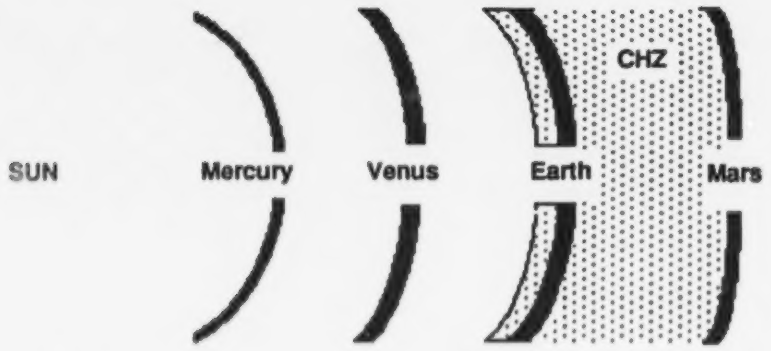

Figure 5. - CHZ from 0.95 to 1.5 astronomical units.

7) What planets are now within the CHZ?

[Earth and Mars.]

Mars is smaller than Earth. It is still large enough to have an atmosphere, but it is much less dense than Earth's atmosphere. The atmosphere on Mars is composed largely of CO_2. The average surface temperature of Mars is about -60°C. There is water on Mars.

8) Considering Mars' temperature, in what state of matter is the water on Mars?

[Solid.]

There are also large quantities of water that are chemically combined with other substances to form minerals in the rocks on the surface of Mars.

Look at the two photographs in Figure 6. One photograph shows a typical river system on Earth. The other shows a portion of the surface of Mars.

9) What is similar about the two photographs?

[They both show river systems.]

10) Which is older on the Mars photograph, the meteor impact craters or the stream valleys?

[The stream valleys are older.]

How do you know?

[Because meteor craters are superimposed on them.]

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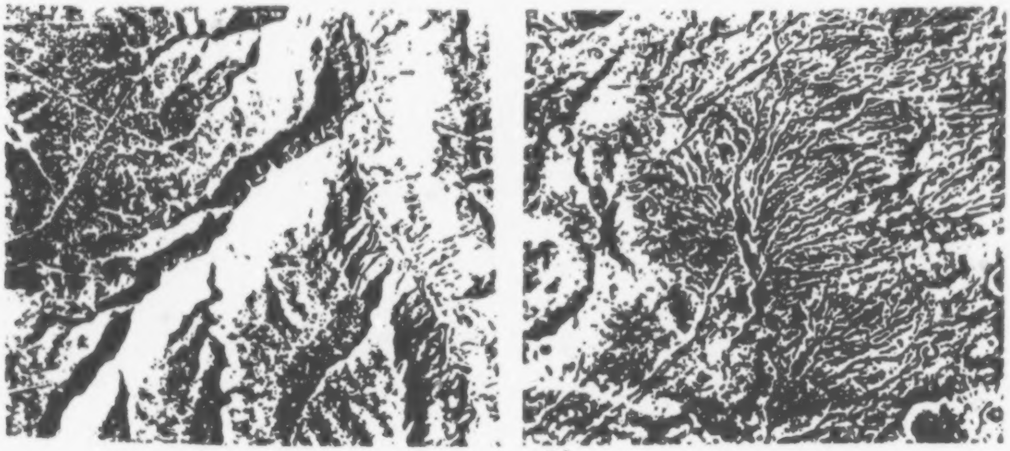
11) The valleys on Mars were formed by water. Was the water a liquid, a solid, or a gas when this happened?

[A liquid.]

What does this tell you about the temperature of Mars at the time the stream valleys were formed?

[It was warmer than it is now.]



EARTH

MARS

Figure 6. - Photographs of parts of the surfaces of Earth and Mars

The meteor impact craters are probably about 3 to 3.5 billion years old. This was very early in the history of the solar system when there was still much debris that impacted on all the planets.

12) The temperature of Mars was different early in its history than it is now. Explain how it was different and how we know.

[It was warmer because liquid water had formed the stream valleys.]

It is quite possible that there was much more CO_2 in the atmosphere of Mars when it was young than there is now.

13) How can this help explain why Mars had a different temperature in the past?

[With more CO_2 in the atmosphere, more heat was trapped.]

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Scientists do not know whether oceans existed on Mars, but evidence suggests there was a great deal of volcanic activity on Mars in the past. The volcanic activity was probably driven by internal heat from the formation of Mars. Olympus Mons, a very ancient volcano on Mars, is one of the largest in the solar system.

All of the parts of a carbonate-silicate cycle may have existed on Mars early in its history. This means that much more CO_2 could have been in the atmosphere of Mars then than there is now.

14) Is it possible that Mars could have supported life early in its history? Explain.

[Maybe. With liquid water present, life as we know it may have existed.]

15) Mars is much smaller than Earth. It cooled more quickly than Earth and eventually became too cool to support volcanic activity. When this occurred, what happened to the carbonate-silicate cycle?

[The cycle, as we know it, stopped.]

How did the amount of CO_2 in the atmosphere and the temperature of Mars change as a result?

[The amount of CO_2 was probably reduced. The temperature decreased.]

Mars has polar ice caps that may be composed largely of frozen CO_2.

16) From where might this CO_2 have come?

[The atmosphere.]

17) If this is true, and if humans wish to colonize Mars one day, how might we be able to make the surface of Mars warmer?

[Humans could add CO_2 to the atmosphere — from chemical compounds in the rocks and soil or maybe from the polar caps.]

18) There is increasing evidence that our solar system is not the only one that exists in our galaxy. If there are other solar systems, and if Kasting's, et al., model is correct about a CHZ, then how likely do you think it is that life exists somewhere outside our solar system?

[Answers will vary. If the planets are similar and composed of the same materials, then there may be carbonate-silicate cycles and other cycles going on that could support life.]

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In Activity C, we have examined the characteristics of Mars and Venus in light of the possibilities of discovering life on them. The fact that Venus is "too hot" and Mars is "too cold" and that Earth is "just right" for life, has led some scientists to call what we have discussed about these three planets the "Goldilocks Problem."

Extensions:

1) You live on a planet in a distance galaxy. Rumors abound concerning a planet in another galaxy that is beautiful. Scientists are doubtful about the existence of this 'blue planet'. You hear of an exploration flight to investigate these rumors and have been selected to be a member of the team. Describe what you see as your ship enters this solar system and you head toward the 'blue planet'. As you orbit the planet, your cameras obtain some wonderful pictures. Describe the scenes that you have experienced. (You should give a two minute presentation to your class on what you saw.)

2) As you have discovered from this activity, Earth is unique in the solar system. It possesses life, it is a planet of rare beauty and great value. Every subsystem of the planet contributes to creating an environment conducive to life. Select one species that inhabits an area of the planet and show how the interactions of the subsystems help this organism survive.

3) Of the two planets nearest Earth, Mars is the one that seems to have the best possibility of life sustaining conditions. Scientists are speculating that it may be possible to alter the atmosphere on Mars with the result that the temperature will increase, CO_2 levels will increase and the solid water will melt. Is this possible? How long do you think such a process would take? Should humans expect experiments such as this to save our species? Is it possible to produce conditions similar to Earth on another planet, attempting to duplicate processes and subsystems that have taken over 4 billion years to develop?

4) Many careers are involved in astronomy and space exploration. These include astronauts, engineers, physicists, biologists, mineralogists, chemists, etc. Some of the products that are used in everyday life were designed for the space exploration programs. One example is superglue, which was developed for quick repairs aboard spacecraft. Find two more examples and show how these have impacted life here on Earth.

Teacher Background Information:

Kluger, J. 1992. "Mars, In Earth's Image." *Discover.* September. 13 (9) : 70 - 75. This article examines the possibility of creating an Earth on Mars. The author speculates on the time frame needed to complete this process and the procedure to be followed to complete this planetary experiment. It may seem like science fiction at present, but some scientists believe this to be a feasible project.

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Moore, P. and Hunt, G. 1990. *The Atlas of the Solar System.* New York: Crescent Books.
The sections concerning Mars and Venus document the characteristic features of these planets. Features for Mars include craters, canyons and volcanoes. Diagrams and color plates help to visualize the planets and their atmospheres.

References:

Boden, T. A., Kanciruk, P. and Farrell, M. P. 1990. *Trends '90 A Comparison of Data on Global Change.* Oak Ridge, TN: Carbon Dioxide Information Analysis Center. 266 pp.

Graedel, T. E. and Crutzen, P. J. 1993. *Atmospheric Change : An Earth System Perspective.* New York: W. H. Freeman and Company.
This recent publication examines the effect of atmospheric change on Earth and its subsystems. It contains relevant and up to date research.

Hart, Michael H. 1988. In Kasting et al. "How Climate Evolved on the Terrestrial Planets." *Scientific American.* 258 (2) : 90 - 97.

Houghton, J. T., Jenkins, G. J., and Ephraums, J. J. 1990. *Climate Change: The IPCC Scientific Assessment.* New York: Cambridge University Press.

Kasting, J. F., Toon, O. B. and Pollack, J. B. 1988. "How Climate Evolved on the Terrestrial Planets." *Scientific American.* 258 (2) : 90 - 97.

Winton, I. 1991. In Pearce, F. *The Big Green Book.* New York: Grosset and Dunlap, Inc.

VIDEO:

WGBH Educational Foundation. 1986. "Goddess of the Earth." *Nova.*
This production deals with many different aspects of Earth, including the Goldilocks Problem and the Gaia Principle. The section on the Goldilocks problem has excellent graphics and commentary on this scientific theory.

HELPFUL DEFINITIONS (VOCABULARY)

CHZ: Continuously Habitable Zone — all possible distances from the sun within which life as we know it could exist on a planet.

Astronomical unit: the average distance from Earth to the sun 150,000,000 km.

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Greenhouse effect: "the trapping by atmospheric gases of outgoing infrared energy emitted by Earth. Part of the radiation absorbed by the atmosphere is returned to Earth's surface, causing it to warm" (Graedel and Crutzen, 1993, 430). Principal greenhouse gases are H_2O vapor, CO_2, O_3, CH_4, N_2, O, CF_2Cl_2, and $CFCl_3$.

Luminosity: the average brightness of a star, in this case, the sun.

Albedo: a measure of the quantity of light reflected by an object.

Subduction: the leading edge of a lithospheric plate subsides into the mantle; generally associated with lines of volcanoes, mountain building and oceanic trenches.

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Global Warming:

How Good is the Evidence?

Will satisfying the energy needs of an expanding human population rapidly change the climate of the Earth? Just how good is the evidence that the Earth is warming? Discovering the answers to these two questions creates a high stake debate which pits society's short-term well being against the future of the Earth's inhabitants. Most climatologists agree that current global warming from an enhanced greenhouse effect might be difficult to detect against the background noise of natural climate variations. However, most are certain that as gases generated by human activities continue to accumulate in the atmosphere, increases in the Earth's temperature will become evident even to the skeptics.

If the reality of global warming were put on trial, each side would have trouble making its case. The primary evidence for such a debate would be temperature records and carbon dioxide levels. How good are these records? What would have happened to the Earth's temperature without the influence of human activity? Figure 1 shows that while atmospheric carbon dioxide has climbed steadily for more than a century, the Earth's temperature shows a more erratic trend.

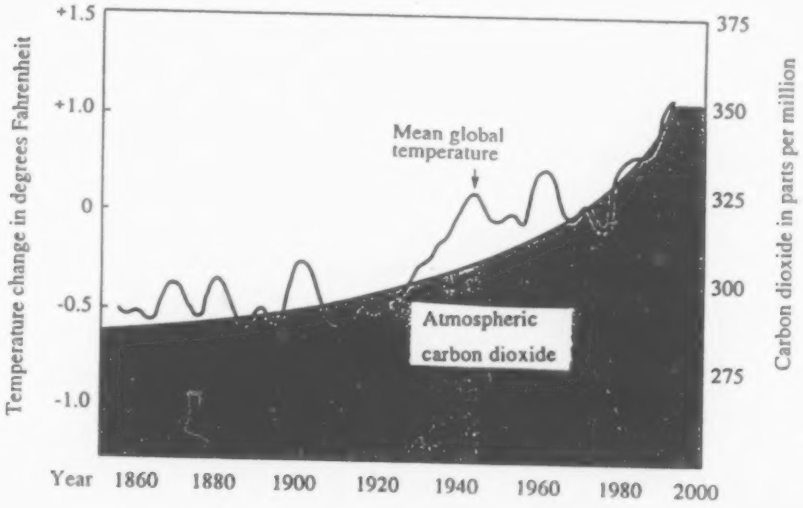

Figure 1. - **Carbon Dioxide levels and mean Global Temperature records from 1850, projected to the end of the century. An increase of 1°F is projected by the year 2000. (Source: Joe LeMonnier, courtesy of *Natural History* Magazine.)**

Activities for the Changing Earth System: funded by a grant from the National Science Foundation and with support from The Ohio State University.

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The concepts studied in these activities include: *global warming; CO_2 influence on climate; ice cores* and the *effect of global warming on other systems.*

Objectives: After completing this activity, each student will be able to:

1) graph average annual temperatures for different locations in the U.S. (Activity A)
2) analyze temperature records in order to determine trends (Activity A).
3) compare and contrast temperature trends from different locations in the U.S. (Activity A).
4) graph average annual CO_2 levels from the Mauna Loa data and Vostok ice core data (Activity B).
5) analyze modern Mauna Loa atmospheric CO_2 and Vostok ice core CO_2 data for trends (Activity B).
6) compare the CO_2 graphs with U.S. temperature records examining any possible relationships (Activity B).

Earth Systems Understandings (ESUs): This activity focuses on ESUs 2 and 3. However, the following ESUs are covered in the Extensions — 1,4, 5, 6 and 7. Refer to the Framework for ESE for a detailed description of each understanding.

Activity A: Does the Temperature record confirm climate warming?

On a global basis, temperature records have been maintained by meteorologists since the 1850s. Temperature records for the U.S. only date back to the early 1900s for most locations. The purpose of this activity is to analyze temperature records from different regions in the U.S. and to determine whether temperatures are actually rising or whether the present temperature changes are part of natural fluctuations.

Materials: temperature data for U.S. locations (one example is included on page 264); graph paper, pencil and ruler; transparencies; overhead projector; wall map of the U.S.

[*Trends '90* is an excellent free source for this information, both on disk and in hard copy. *Trends* is an annual publication. Also check references at the end of activity for CD-ROM availability.]

Procedure:

1) Divide the class into groups of 3 or 4 students. Assign groups to graph the temperature records from the list of U.S. locations below:

A) Eastern Prairies
B) South Pacific Coast
C) Great Lakes

D) Great Basin
E) South Coastal Plain
F) Northern Piedmont
G) Coastal Northeast

2) Each group should locate the region of its assigned temperature records and then graph the average annual temperature for the location over an eighty year period. In this case, from 1907 to 1987. Upon completion of the graph each group should receive an overhead transparency and make a copy of the graph for overhead projection.

3) Each group should prepare a two minute presentation for the class. The presentation should include the following information:
  a) the location of the region on a U.S. wall map.
  b) a concise and clear graph of the temperature data.
  c) analysis of any trends or lack of trends in the graph.

4) After all the presentations are completed a discussion should take place which focuses on two key questions:
  a) from all the temperature graphs shown, were any clear warming or cooling trends indicated?
  b) do the temperature records for the U.S. demonstrate that global warming is clearly occurring in the U.S.?

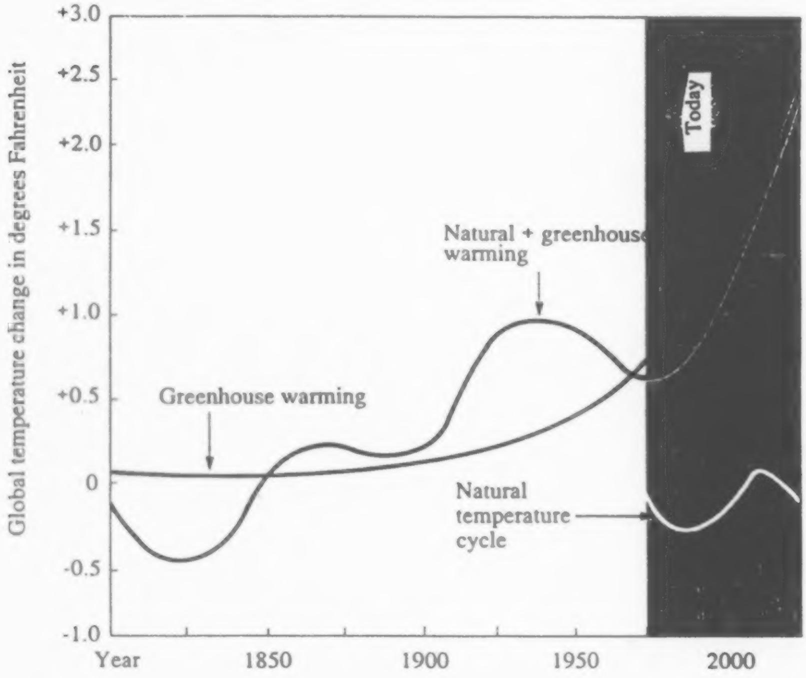

Figure 2. - **Predicting Greenhouse Warming from Natural and Human Causes. (Source: Joe LeMonnier, courtesy of *Natural History* Magazine.)**

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Figure 2 suggests that despite a rise in greenhouse gases, the Earth cooled somewhat during the 1960s and 1970s because it was at a low point of a natural temperature cycle. The warming of the 1980s occurred when the natural cycle again turned upward, no longer masking the effect of increased greenhouse gases.

[In addition discuss the differences between weather and climate. Emphasize that weather is the state of the atmosphere at a given time and place, while climate is a summary of weather conditions in a place or region over a period of time. Refer to the Earth System Processes chart located at the front of the book for a comparison of the time frames involved.]

Activity B: Does the CO_2 record show the potential for an increased greenhouse effect?

The United States continues to be the largest source of CO_2 emissions in the world. Figure 3 shows the sources of CO_2 emissions from the U.S. since 1950.

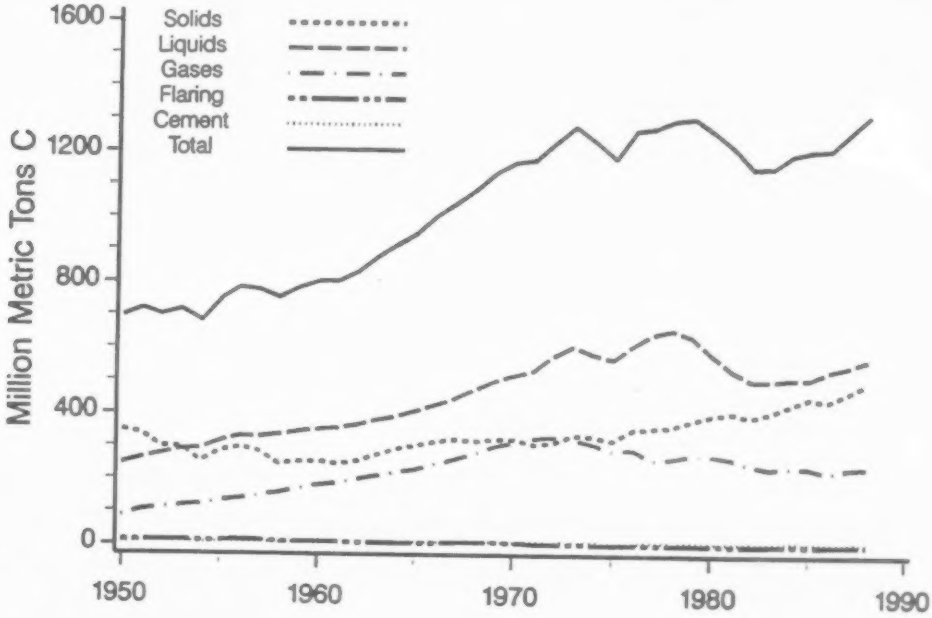

Figure 3. - CO_2 emissions from the U.S. since 1950.
(Source: *Trends '90.*)

Precise records of past and present atmospheric CO_2 levels are critical to understanding any CO_2 induced climate change. The Mauna Loa atmospheric CO_2 measurements in Hawaii constitute the longest direct record of atmospheric CO_2 available in the world. The record dates back to 1958. In addition, past levels of atmospheric CO_2 have been made using direct measurements of trapped air in polar ice cores. Ice core records document CO_2 levels during the past 160,000 years.

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Figure 4 shows the annual atmospheric CO_2 concentrations during the past 160,000 years. The graph uses both ice core and the modern Mauna Loa data on CO_2 concentrations.

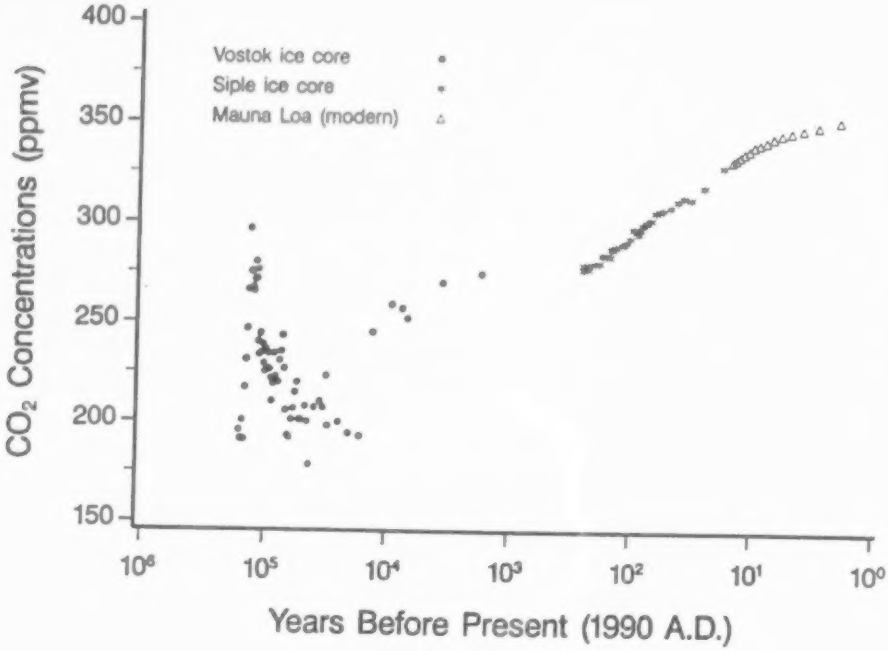

Figure 4. - Annual atmospheric CO_2 concentrations during the past 160,000 years. (Source: *Trends '90.*)

The purpose of this activity is to compare CO_2 measurements from Mauna Loa and Vostok ice cores to discover if there is any evidence that atmospheric CO_2 concentrations have risen over the past three decades as the result of human activity. Carbon dioxide measurements from Mauna Loa can then be compared with temperature records from the rest of the U.S. in order to investigate any relationship between CO_2 concentrations and temperature fluctuations.

Materials: Mauna Loa CO_2 record (page 265); Vostok CO_2 ice core record (page 266); handout of six or seven temperature record graphs from U.S. (completed in Activity A); graph paper; pencil and ruler.

Procedure:

1) Using the CO_2 record from Mauna Loa each student should graph the annual CO_2 concentrations from 1958 until 1987.

2) Using the CO_2 record from the Vostok ice core each student should graph the annual CO_2 concentrations from 160,000 to 4,000 years ago.

3) After completing the graph each student should compare the trends in CO_2 concentrations from Mauna Loa and Vostok ice cores with the temperature records from the six or seven sites in the U.S.

Evaluation:

Each student should write a position paper that includes a discussion of the following:

A) analyze Mauna Loa and Vostok ice core CO_2 data and suggest how we would know if human activity is having an impact on CO_2 levels.
B) do temperature records for the U.S. demonstrate that global warming is clearly occurring in the U.S.?
C) what relationships exist between CO_2 concentrations and U.S. temperatures?

All conclusions should be completely supported by the data and graphs from the two activities.

Extensions:

1) The Earth is unique in our solar system, in that it is the only planet that can support life, as we know it. What impact might global warming have on this life support system? Is the planet valuable enough to us to change human induced CO_2 levels?

2) Describe the influence of global warming on the following:
   a) physiological processes of life on the planet.
   b) the atmosphere.
   c) the polar ice caps and glaciers.
   d) the lithosphere.
   e) the hydrosphere.

If global warming has an influence on each subsystem, what effect does it have on the interactions between these systems? Discuss your answer and support it with evidence.

3) Planet Earth is more than 4 billion years old. One billion years after its formation, life began its development, culminating in the present complex, dynamic life support system. Global warming could have a major impact on this continually evolving system. You (individually or as a small group) are to make a presentation to the United Nations, calling for an investigation into the situation. State how you would do this, the information you would use, witnesses you would call, etc. Then make your presentation to the class and possibly your school.

An alternative is to set up a trial situation, similar to that in the article "Global Warming on Trial" from *Natural History*, April 1992. The students should act as the

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witnesses, scientists, industrialists and judge. The remainder of the class could compose the jury. Let them decide, from the present evidence and the information acquired in this activity, the current situation and the possible future implications for themselves and the planet.

4) Other planets have undergone global warming. Study these planets and determine from this information if planet Earth could become such a planet in the future. Support your position with evidence and if you believe this is possible, state how the process could be arrested.

5) Describe the training of three kinds of scientists who might be involved in researching the problem of global warming. Select two other careers unconnected with this problem and discuss how global warming could impact them.

6) Do the terms global warming and global climate change have the same meaning? What do you understand the terms to represent? We have seen that volcanoes may often mask the influence of global warming (see Volcanic Eruptions and Global Climate Change activity). What influence would this have on global and regional temperatures? In what other ways could global climate change be recorded or measured? Examine the weather patterns of recent years - are they of any assistance in determining if the world climate and weather patterns are in flux?

> [Information on major climatic/weather events should be considered in this activity. Include the following: El Niño and its influence in the Pacific; the hurricanes of 1992; the severity and number of storms in recent years; the temperature and precipitation records for the last few U.S. summers and the drought in the Western U.S.]

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Great Lakes

Average Temperature (°C), 1901–1987

Year	Ann*	Win	Spr	Sum	Fall	Ann†
1901	7.26	–6.78	6.48	21.35	8.82	7.47
1902	7.51	–6.83	7.87	18.78	10.00	7.46
1903	6.98	–6.37	8.48	18.35	8.42	7.22
1904	5.86	-10.4	5.54	18.56	9.04	5.69
1905	6.87	–9.01	6.78	19.56	9.01	6.58
1906	7.79	–4.07	5.85	20.07	9.67	7.88
1907	6.51	–5.98	4.75	18.81	8.07	6.41
1908	8.00	–5.04	7.36	19.68	10.40	8.10
1909	7.27	–4.50	5.37	19.95	9.31	7.53
1910	7.57	–7.39	8.57	20.11	8.81	7.52
1911	8.16	–5.39	7.71	20.53	7.99	7.71
1912	6.46	–8.39	5.68	18.87	9.94	6.52
1913	8.15	–5.01	6.52	20.52	9.99	8.01
1914	7.48	–4.92	6.69	20.30	10.10	8.04
1915	7.41	–5.87	6.79	17.70	10.15	7.19
1916	7.11	–5.97	5.65	20.55	8.90	7.28
1917	5.42	–8.52	5.04	18.81	7.13	5.62
1918	7.46	–9.77	7.94	20.05	8.81	6.76
1919	7.91	–2.85	6.63	21.17	9.46	8.60
1920	7.21	–9.10	5.79	19.35	10.67	6.67
1921	9.49	–2.95	9.60	21.95	9.72	9.58
1922	8.19	–5.66	8.13	19.97	10.74	8.29
1923	7.49	–6.35	5.07	20.24	9.16	7.03
1924	6.24	–4.97	5.09	18.61	9.12	6.96
1925	7.43	–6.36	7.36	20.26	7.79	7.26
1926	6.52	–5.60	4.64	19.16	7.96	6.54
1927	7.70	–5.40	7.12	18.05	10.74	7.63
1928	7.56	–5.26	5.91	19.27	9.23	7.29
1929	6.74	–7.21	7.69	19.14	8.28	6.97
1930	8.11	–5.21	7.15	20.62	9.60	8.04
1931	9.69	–3.04	6.61	21.20	12.55	9.33
1932	7.96	–1.13	5.47	20.69	8.36	8.35
1933	8.35	–3.87	6.83	21.48	9.01	8.36
1934	8.04	–5.78	6.75	21.31	10.32	8.15
1935	7.28	–5.93	6.10	20.27	8.77	7.30
1936	7.26	–9.31	7.12	21.12	8.78	6.93
1937	7.39	–4.37	5.90	20.91	8.28	7.68
1938	8.68	–4.96	8.37	20.50	10.17	8.52
1939	8.36	–4.67	6.68	20.58	9.94	8.13
1940	6.98	–5.52	4.72	20.10	9.09	7.10
1941	8.68	–4.71	7.56	20.54	10.74	8.53
1942	7.85	–4.40	8.49	20.01	9.30	8.35
1943	7.14	–6.47	5.24	21.08	8.00	6.96
1944	8.24	–3.80	6.41	21.00	10.06	8.42
1945	7.29	–7.01	8.30	18.95	9.11	7.33
1946	8.63	–5.81	8.85	19.31	10.69	8.26
1947	7.64	–4.91	5.08	20.41	10.44	7.75
1948	7.79	–6.67	7.07	20.12	10.34	7.71
1949	8.64	–3.82	7.28	21.58	9.36	8.60
1950	6.70	–4.13	4.76	18.75	9.04	7.10
1951	6.99	–6.42	6.77	18.93	7.87	6.79
1952	8.32	–4.37	6.79	20.88	8.91	8.05
1953	8.85	–3.03	6.86	20.81	10.91	8.89
1954	8.24	–3.05	6.30	20.21	9.92	8.34
1955	8.28	–5.17	8.40	21.54	9.19	8.49
1956	7.77	–5.69	5.67	19.87	9.87	7.43
1957	7.78	–4.95	7.01	20.16	8.80	7.76
1958	7.16	–5.21	7.14	18.84	10.09	7.71
1959	7.83	–8.20	7.54	21.12	8.41	7.22
1960	7.35	–3.80	5.25	19.40	10.33	7.79
1961	7.85	–5.52	6.19	19.86	10.46	7.75
1962	7.21	–7.09	7.48	19.44	9.26	7.28
1963	7.14	–9.05	7.20	19.87	11.55	7.39
1964	8.14	–5.89	7.85	19.92	9.44	7.83
1965	7.35	–6.40	6.03	18.94	9.28	6.96
1966	7.25	–5.10	6.12	20.37	8.88	7.57
1967	7.11	–5.71	6.15	19.28	8.24	6.99
1968	7.84	–5.83	7.82	20.01	10.02	8.00
1969	7.37	–5.60	6.76	19.55	8.82	7.38
1970	7.67	–7.21	6.99	20.61	10.06	7.61
1971	7.80	–6.40	5.71	19.93	11.25	7.62
1972	6.68	–5.80	6.13	19.18	8.26	6.94
1973	8.77	–4.80	8.00	20.99	10.68	8.72
1974	7.60	–5.65	7.01	19.78	8.67	7.45
1975	8.02	–4.09	6.09	20.49	9.95	8.11
1976	7.10	–4.62	7.75	20.19	6.80	7.53
1977	7.77	–9.29	10.39	19.67	9.26	7.51
1978	6.78	–8.77	6.04	19.80	9.80	6.72
1979	6.80	–9.15	6.51	19.41	9.32	6.52
1980	7.30	–5.28	6.82	20.30	8.56	7.59
1981	7.82	–5.54	7.64	20.08	8.80	7.74
1982	7.33	–7.71	7.02	18.89	9.62	6.95
1983	8.12	–2.10	6.22	21.56	10.05	8.93
1984	7.90	–6.41	5.33	20.60	9.63	7.27
1985	7.44	–5.93	9.40	18.95	9.56	8.00
1986	8.18	–6.87	8.82	19.68	9.08	7.68
1987	9.31	–3.17	9.48	21.29	9.25	9.21

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*Calendar year mean (Jan–Dec).

†Season year mean = (Win = Dec–Feb; Spr = Mar–May; Sum = Jun–Aug; Fall = Sep–Nov).

(Source: *Trends '90. A Compendium of Data on Global Change.*)

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Mauna Loa

Atmospheric Concentrations of Carbon Dioxide*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
1958			316.0	317.6	317.8		316.1	315.2	313.4	313.5		314.8	
1959	315.6	316.4	316.8	317.8	318.4	318.2	316.7	315.0	314.0	313.6	315.0	315.8	316.1
1960	316.5	317.1	317.8	319.2	320.1	319.7	318.3	316.0	314.2	314.1	315.1	316.2	317.0
1961	317.9	317.8	318.5	319.5	320.6	319.9	318.7	317.0	315.2	315.5	316.2	317.2	317.7
1962	318.1	318.7	319.8	320.7	321.3	320.9	319.8	317.6	316.5	315.6	316.9	317.9	318.6
1963	318.8	319.3	320.1	321.5	322.4	321.6	319.9	317.9	316.4	316.2	317.1	318.5	319.1
1964	319.6				322.2	321.9	320.4	318.6	316.7	317.2	317.9	318.9	
1965	319.7	320.8	321.2	322.5	322.6	322.4	321.6	319.2	318.2	317.8	319.4	319.5	320.4
1966	320.4	321.4	322.2	323.5	323.8	323.5	322.2	320.1	318.3	317.7	319.6	320.7	321.1
1967	322.1	322.2	322.8	324.1	324.6	323.8	322.3	320.7	319.0	319.0	320.4	321.7	322.0
1968	322.3	322.9	323.6	324.7	325.3	325.2	323.9	321.8	320.0	319.9	320.9	322.4	322.8
1969	323.6	324.2	325.3	326.3	327.0	326.2	325.4	323.2	321.9	321.3	322.3	323.7	324.2
1970	324.6	325.6	326.6	327.8	327.8	327.5	326.3	324.7	323.1	323.1	324.0	325.1	325.5
1971	326.1	326.6	327.2	327.9	329.2	328.8	327.5	325.7	323.6	323.8	325.1	326.3	326.5
1972	326.9	327.8	328.0	329.9	330.3	329.2	328.1	326.4	325.9	325.3	326.6	327.7	327.6
1973	328.7	329.7	330.5	331.7	332.7	332.2	331.0	329.4	327.6	327.3	328.3	328.8	329.8
1974	329.4	330.9	331.6	332.9	333.3	332.4	331.4	329.6	327.6	327.6	328.6	329.7	330.4
1975	330.5	331.1	331.6	332.9	333.6	333.5	331.9	330.1	328.6	328.3	329.4	330.6	331.0
1976	331.6	332.5	333.4	334.5	334.8	334.3	333.0	330.9	329.2	328.8	330.2	331.5	332.1
1977	332.8	333.2	334.5	335.8	336.5	336.0	334.7	332.4	331.3	330.7	332.1	333.5	333.6
1978	334.7	335.1	336.3	337.4	337.7	337.6	336.2	334.4	332.4	332.2	333.6	334.8	335.2
1979	335.9	336.4	337.6	338.5	339.1	338.9	337.4	335.7	333.6	333.7	335.1	336.5	336.5
1980	337.8	338.2	339.9	340.6	341.2	340.9	339.3	337.3	335.7	335.5	336.7	337.8	338.4
1981	338.8	340.1	340.9	342.0	342.7	341.8	340.0	337.9	336.2	336.3	337.8	339.1	339.5
1982	340.2	341.1	342.2	343.0	343.6	342.9	341.7	339.5	337.8	337.7	339.1	340.4	340.8
1983	341.3	342.5	343.1	344.9	345.8	345.3	344.0	342.4	339.9	340.0	341.2	342.9	342.8
1984	343.7	344.6	345.3	347.0	347.4	346.7	345.4	343.2	341.0	341.2	342.8	344.0	344.3
1985	344.8	345.8	347.2	348.1	348.7	347.9	346.3	344.2	342.9	342.6	344.0	345.3	345.7
1986	346.0	346.7	347.6	349.2	349.9	349.2	347.7	345.5	344.5	343.9	345.3	346.6	346.9
1987	347.7	348.1	349.1	350.6	351.5	351.0	349.2	347.7	346.2	346.2	347.4	348.7	348.6
1988	349.9	351.2	351.9	353.2	353.9	353.3	352.1	350.0	348.5	348.7	349.8	351.1	351.2
1989	352.5	352.8	353.4	355.1	355.4	354.9	353.4	351.3	349.6	349.9			

(Source: *Trends '90. A Compendium of Data on Global Change.*)

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*Atmospheric CO₂ in parts per million by volume (ppmv). Annual averages based on monthly means. All numbers have been rounded to the nearest tenth.

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Vostok

Atmospheric Concentrations of Carbon Dioxide from Ice Cores

Depth (m)	Age of the ice (yr BP)	Mean age of the air (yr BP)	CO_2 concentration (ppmv)
126.4	4,050	1,700	274.5
173.1	5,970	3,530	270.0
250.3	9,320	6,800	252.0
266.0	10,040	7,500	257.0
302.6	11,870	9,140	259.0
375.6	16,350	12,930	245.0
426.4	20,330	16,250	193.0
474.2	24,280	20,090	194.5
525.1	28,530	24,390	200.0
576.0	32,680	29,720	198.0
602.3	34,770	30,910	223.0
625.6	36,600	32,800	207.0
651.6	38,600	34,870	210.0
700.3	42,320	38,660	207.0
718.2	45,970	42,310	178.5
775.2	48,000	44,350	200.0
800.0	49,850	46,220	207.7
852.5	53,770	50,150	201.0
874.3	55,450	51,770	201.0
902.2	57,660	53,860	219.5
926.8	59,670	55,780	214.5
951.9	61,790	57,800	206.5
975.7	63,880	59,770	201.0
1002.5	66,230	62,080	192.0
1023.5	68,040	63,960	193.0
1052.4	70,470	66,540	205.5
1074.8	72,330	68,490	226.5
1101.4	74,500	70,770	243.0
1124.2	76,330	72,690	235.0
1148.7	78,270	74,720	230.5
1175.0	80,320	76,860	219.5
1225.7	84,220	80,900	222.5
1251.5	86,220	82,920	234.0
1274.2	87,980	84,700	218.8
1299.3	89,940	86,680	210.0
1322.5	91,760	88,520	221.5
1349.0	93,860	90,630	226.0
1374.8	95,910	92,700	234.0
1402.5	98,130	94,940	226.5
1425.5	100,000	96,810	236.0
1451.5	102,210	98,950	225.0
1476.1	104,410	101,040	229.0
1499.6	106,610	103,130	238.5
1526.3	109,240	105,620	234.5
1547.0	111,250	107,650	244.0
1575.2	113,850	110,510	233.5
1598.0	115,850	112,700	240.0
1626.5	118,220	115,290	276.0
1651.0	120,170	117,410	271.5
1676.4	122,100	119,500	280.0
1700.9	123,900	121,430	271.0
1726.8	125,730	123,380	265.3
1747.3	127,150	124,880	267.0
1774.1	129,020	126,770	275.0
1802.4	131,030	128,780	266.5
1825.7	132,700	130,460	275.0
1850.5	134,510	132,280	266.0
1875.9	136,450	134,170	296.5
1902.0	138,660	136,170	266.0
1928.0	141,170	138,410	246.5
1948.7	143,440	140,430	231.0
1975.3	146,860	143,370	217.0
1998.0	150,330	146,340	191.0
2025.7	154,980	150,700	200.5
2050.3	159,100	154,970	191.3
2077.5	163,670	159,690	195.5

(Source: *Trends '90. A Compendium of Data on Global Change.*)

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Teacher Background Information:

A Co-Production of Maryland Public T.V., Film Australia, Wiseman UK, Electric Image (UK) in Association with Principal Film Company Ltd. (UK). *After the Warming.* 1990.
Excellent 2 hour presentation integrating all the available evidence. A scenario of global warming and its consequences is portrayed.

Houghton, R. A. and Woodwell, G. M. 1989. "Global Climatic Change." *Scientific American.* 260 (4) : 36 - 44.
This article examines the different sources of evidence of climatic changes. It discusses glacial retreat, using specific glaciers in Alaska and Switzerland; it investigates rises in greenhouse gases, and it examines ice core data. The authors also predict certain results of climate change.

Udall, J. R. 1989. "Climate Shock." *Sierra* . 74 (4) : 26 - 40. San Francisco.
A historical and current reporting on the situation of this issue. It also gives suggestions on the way the general public can help to alleviate the situation.

References:

Hall, D. K. 1989. "Global Climate Change." *The Science Teacher.* 56 (6) : 66 -70.

Trends '90. A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center. Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831.
An example of one data sheet is included for this activity.
(This is an annual publication, with updated information and new studies included each year.)

Broecker, W. S. 1992. "Global Warming on Trial." *Natural History.* April. 4 : 6 -14.

LeMonnier, J. 1992. IN Broecker, W. S. 1992. "Global Warming on Trial." *Natural History.* April. 4 : 6 -14.

The CD-ROM entitled *"National Climate Information Disk Volume 1"* contains 95 years worth of precipitation, temperature, and drought data for the contiguous United States. The data on the CD-ROM disk is intended for use on an IBM computer system using software loaded on the disk itself. To view the data and create graphical interpretations on a Macintosh system, however, is possible. For each category of data - precipitation, temperature and drought — a single file exists on the CD. The file contains numbers in ASCII, a format easily understood by several applications. National Oceanic and Atmospheric Administration (NOAA) sells the CD for $69 (inclusive of tax, 1992 price).

The agency's National Climate Data Center in Asheville, NC, will search the dataset and provide information for desired areas. Cost for this service depends on the location and the type of information required. Information requests can be directed to

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National Climate Data Center, NESDIS - NOAA, Federal Building, Asheville, NC 28801-2696, or by phone to NCDC at 704/259-0682.

VIDEO:

WGBH Foundation. 1990. "Only One Atmosphere." *Race to Save the Planet*. This program examines the consequences of an altered climate and its impact on different aspects of human life. Real life situations are used as examples.

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FACT SHEETS

AND

REFERENCES FOR

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GLOBAL CHANGE IN THE GREAT LAKES

Understanding Climate Models

Throughout the past decade, advances in computer and communication technologies have allowed people in the world's more developed countries to generate, access, and share enormous amounts of information. Private satellite dishes and cable television, for example, convey real-time images of people, places, and events throughout the world; and personal computers allow people to access databases and data management programs from the privacy of their homes and offices.

An important component of this communications revolution has been the media, which have been instrumental in helping the public keep up with — and, in some instances, understand — developments in the world around them. In their quest to provide people with up-to-the-minute information, the media have drawn all sorts of important issues into the public forum for debate. Perhaps no body of knowledge has been more affected by the media's aggressive investigation of new information than science.

Once almost entirely confined to scientific journals, scientific controversies have found their way into everyone's daily life, thanks to the media. People have come to expect that when they read or listen to news reports, they are likely to be informed of the results of one scientific study or another. Instead of reporting scientists' final consensus on an issue, however, the media often follow a scientific question through months or years of debate. While this ensures that the public is kept informed of the progress of research, it also lends to the public's confusion over issues on which experts cannot seem to agree.

The Global Warming Debate

A current example of confusing scientific debate centers around scientists' interpretations of what the Earth's climate will be like in the next century.

Most members of the scientific community agree that if concentrations of certain greenhouse gases increase, global climate will change. Few, however, agree on when these changes will occur and how extensive they will be.

Greenhouse gases such as carbon dioxide, methane, and water vapor occur naturally in the atmosphere and help warm the earth by absorbing infrared radiation emitted by the Earth's surface. If this did not happen at all, the planet would be uninhabitable. At issue is the role of human activities such as deforestation and the burning of fossil fuels in amplifying the greenhouse effect by increasing greenhouse gas concentrations in the atmosphere. If current trends in emissions continue, scientists predict that a 1.5 to 4.5°C warming of the Earth will probably occur near the middle of the next century. If this warming occurs, it could have significant effects on such climate variables as precipitation and wind patterns. These, in turn, will affect agriculture, water resource availability, regional weather conditions, and many other things that directly affect human life and the world as we know it.

A few scientists, however, are not convinced that the Earth will experience a significant amount of warming as a result of an enhanced greenhouse effect. According to them, the Earth's physical processes are flexible enough to accommodate the additional greenhouse gases emitted by human activity. They believe the world's oceans, for example, are capable of absorbing and storing much more CO_2 than they currently do. If a slight global warming does occur, these scientists believe its effect on humanity will be minimal.

The key to understanding the global warming debate is to understand how it is possible for scientists to generate different interpretations of future climate on Earth. Then, by recognizing the strengths and weaknesses of scientists' climate research, the debate over global warming becomes easier to follow.

Climate Models

To predict future global climate, scientists start with information about the present climate and try to make reasonable assumptions about what will happen in the next century. Then, they use computerized climate models to assimilate this information and come up with a description of future climate.

> ***"A current example of confusing scientific debate centers around scientists' interpretations of what the Earth's climate will be like in the next century."***

> ***"The key to understanding the global warming debate is to understand how it is possible for scientists to generate different interpretations of future climate on Earth."***

We use models in our everyday life to represent a variety of objects, processes, and systems. Because models are only *representations* of real things, however, we do not expect them to be exactly like the things we try to imitate. We know, for example, that while a model train may have the same shape as a real train, it is much smaller and cannot transport the same amount of cargo.

Even though models are not precise replicates, they still provide useful information. Dummies used in car crash simulations, for example, are far from being human, yet the information they provide engineers helps car manufacturers design safer vehicles. Similarly, global change models used today may not function exactly like the real climate, but the information they generate helps scientists understand the possible implications of global climate change.

For a climate model to function as realistically as possible, there are a number of physical laws, such as the law of conservation of energy, that scientists must incorporate. Climate variables associated with these laws include precipitation, temperature, and wind patterns, all of which interrelate and help determine how the total Earth system functions. Scientists express these laws and variables as mathematical equations, which are entered into a computer along with information on past and present global conditions. To this, scientists add their reasoned assumptions.

The simplest climate models are one- and two-dimensional simulations that try to predict the average climate across the Earth as a whole, but not regional variations. A major flaw is that they cannot incorporate many of Earth's important physical processes. The types of models most often used today are three-dimensional models known as General Circulation Models (GCMs). These allow scientists to investigate a large number of climate variables simultaneously, and results can be applied to specific regions of the Earth — such as the Great Lakes.

Because GCMs are predominantly concerned with atmospheric circulations, scientists often start with GCM information, then add data from smaller models of physical processes such as ocean circulation or cloud formation. This process is sometimes referred to as the *coupling* of climate models.

The Reliability and Validity of Climate Models

The reason there is so much disagreement in the scientific community about global climate change is that the reliability and validity of the climate models currently being used are questionable on several counts.

Testing Climate Models

To determine how well a climate model works, modelers "validate" their models by comparing them to the real world. In other words, models are provided with information about today's climate as input and are expected to produce data that closely resembles today's climate. Critics claim that some of the climate models used today have not been validated, and that those that have are not accurate.

Spatial Resolution

Modelers generally divide the world into a number of three-dimensional columns of air that extend upward from the surface of the Earth. Temperature, pressure, precipitation, and other properties of each column are translated into mathematical equations and fed into a computer along with modelers' assumptions. The equations are solved for each column of air and the computer generates a description of what global climate in these regions will be like in the future. Unfortunately, computer speed and other constraints limit the number of columns into which modelers can divide the Earth. As a result, the average size of these columns of air is 300 miles on each side — roughly the size of the state of Wyoming. This poor *spatial resolution* makes it nearly impossible for modelers to predict regional differences in such variables as precipitation, temperature, and wind velocity. Our experience tells us, however, that on any given day the weather in one part of a state may be very different than in another.

One way to improve the spatial resolution of GCMs would be to use faster, more powerful computers. Unfortunately, modern machines cannot accommodate the thousands of equations necessary to make this possible. According to physicist James Trefil of George Mason University, if modelers reduced the size of atmospheric columns used in a GCM from 300 to 30 miles per side, the best of today's computers would take 40 years to generate a prediction of future climate. Ironically, such calculations would come too late to be of much assistance to scientists and policymakers interested

Major Features of Three General Circulation Models (GCMs)*

GCM	When Calculated	Model Resolution (Lat. x Long.)	Temperature Increase for Doubled CO_2 (°C)	Increase in Global Precipitation (%)
Goddard Institute for Space Studies (GISS)	1982	8 x 10°	4.2	11.0
Geophysical Fluid Dynamics Laboratory (GFDL)	1984-85	4 x 8°	4.0	8.7
Oregon State University (OSU)	1984-85	4 x 5°	2.8	7.8

* Assuming that CO_2 doubling will occur in the middle of the next century.

Source: U.S. Environmental Protection Agency (1989)

in making proactive decisions. However, recent advances in technologies such as superconductivity make scientists hopeful that a new breed of computers will evolve that can make high resolution GCMs possible.

Assumptions

Another reason people question the reliability of climate models is that although scientists agree on some of the initial conditions to set for climate models, they often make different assumptions about other physical processes related to their models. While there is a consensus on how temperature and wind velocity should be measured, for example, there is no standard way to compute things like cloud height, the movement of sea ice, or surface *albedo* (the ratio between the light reflected by an object and the total light falling on its surface). Scientists do not yet know enough about these physical processes to gather and interpret information about them consistently. Depending on their assumptions about these different physical processes, climate modelers can come up with very different interpretations of the future, as evidenced by the GCMs of the three leading global change research institutions, shown above.

The more physical processes modelers try to incorporate into their models, the more assumptions they have to make about processes related to climate. The number of assumptions multiplied, then, when scientists link models together or use output from one model as input for another model. Since not all modelers' assumptions about climate are correct, the more assumptions involved in a model, the greater the error. The key to improving climate models is to gain a better understanding of the physical processes that drive the individual components of climate.

Characteristics of Some Variables Involved in Climate Modeling

To appreciate the complexity of climate models, here are a few examples of the kinds of variables that modelers must incorporate into their models.

Oceans

The primary function of oceans in regard to climate is to absorb, release, and distribute atmospheric heat on the Earth's surface. Modeling the oceans presents a particularly difficult challenge for scientists because relatively little is known about the physical processes that affect ocean circulation. For example, scientists have not been able to agree on how to calculate the vertical and horizontal mixing of currents, and they have trouble incorporating information about upwellings into their models. (An *upwelling* is a phenomenon that occurs in oceans and lakes when wind blowing across warm surface water pushes that water away from shore. When this occurs, cold, nutrient-rich water from below is forced to the surface.)

Another important function of oceans is to absorb CO_2 from the atmosphere, but no one knows how much can be taken up. As mentioned earlier, some scientists believe that there is little threat of global warming as a direct result of increased atmospheric CO_2. They think excess CO_2 emitted by human activity will be removed by oceans. Other scientists, however, are quick to point out that the amount of carbon the oceans are able to absorb is a direct function of ocean temperature. Because cool water is capable of absorbing more atmospheric CO_2 than warm water, these scientists are concerned that even a small increase in ocean temperatures in the future will disturb the carbon balance and enhance the greenhouse effect. To make an accurate assessment of the role oceans play in carbon absorption, scientists need to gain a better understanding of the entire carbon cycle: the process whereby carbon is transferred between land, water, living things, and the atmosphere.

> ***"The more physical processes modelers try to incorporate into their models, the more assumptions they have to make about processes related to climate."***

Clouds

Another important climate variable that is difficult to assess is the role of clouds. Depending on their composition and their location in the atmosphere, clouds can perform a variety of functions. By trapping and reflecting the longwave radiation emitted by the Earth's surface, clouds function as insulators, helping keep the Earth warm. Clouds can also trap and reflect the shortwave radiation emitted by the sun. In this case, clouds act as cooling mechanisms and prevent the Earth from becoming unbearably hot.

Despite these significant functions, however, scientists have a difficult time incorporating information about clouds into their models because cloud behavior is difficult to measure, let alone predict. Some researchers have hypothesized, for example, that if the Earth warms, there will be an increased rate of evaporation, which will lead to the formation of more clouds. If these clouds reflect a large amount of incoming shortwave radiation from the sun, they will help cool the Earth and reduce warming. On the other hand, if they trap and reflect longwave radiation, warming could increase.

As with atmospheric circulation models, resolution is a major problem for scientists trying to model both clouds and ocean circulation. Like the atmosphere, clouds and oceans are affected by all sorts of regional climate conditions that make it difficult to predict the future climate at specific points on the globe.

Volcanoes

Many people may not associate volcanoes with climate, but historical records suggest that volcanic eruptions can have significant effects on world climate. Volcanoes can discharge enormous amounts of fine particles and aerosols into the atmosphere, which can decrease the amount of sunlight that is able to reach the Earth's surface. When this happens, the Earth can cool by several tenths of a degree for years, perhaps decades. Examples of this phenomenon are found throughout time, from the volcanic acids deposited in the Greenland ice sheets over a thousand years ago to more memorable eruptions such as Mount Pele and Krakatoa.

Some researchers suggest that the reason the Earth has warmed by 0.3° to 0.6°C in the past 100 years is that there has not been significant volcanic activity. Without the natural cooling that accompanies intense volcanic activity, the Earth has warmed.

Policy Decisions in the Face of Global Warming

According to Trefil, there are three basic responses to the global warming debate that today's leaders can adopt. First, decision makers could adopt a "wait and see" attitude by waiting until scientists can produce indisputable evidence that global warming is or is not continuing to happen. The obvious shortcoming of this policy is that by the time such results become available, it may be too late for policymakers to take steps to help reduce the consequences of global warming if it does, indeed, continue.

Another response would be for policymakers to "assume the worst and act accordingly." This response would require immediate policy decisions designed to drastically reduce human activities that affect climate. Such policies might include a ban on the use of fossil fuels or a halt to deforestation. This would be the best response to help reduce the effects of global warming, but it would bring economic hardship to millions of industries and people.

Finally, decision makers could adopt a "no regrets" policy. "The idea here is to undertake immediately those actions that make sense whether the warming predictions are right or not," said Trefil. In other words, even though scientists cannot definitively agree on whether or not global warming will continue, they do generally agree that human activity is at the heart of many other problems throughout the world. If steps are taken to correct *known* problems such as acid deposition, deforestation, and fossil fuel dependency, they will have the added benefit of helping reduce emissions of greenhouse gases. Although this "middle of the road" approach may seem appealing, it may not initiate the types of policy decisions that would adequately address severe global warming if it were to occur.

Some critics argue that climate models should not be used as guides for making public policy decisions about global warming because these models currently do a poor job describing how the Earth's physical processes work. Despite the models' shortcomings, however, they are still useful in helping scientists assess what the *possible* implications of continued global warming could be.

To appreciate the importance of climate models, consider another type of model relied on daily: weather models. Before people leave their homes in the morning, they generally listen to weather forecasts in order to determine what clothing will be most appropriate for the day and what sorts of outdoor activities the weather will permit. People trust these forecasts enough to make these kinds of decisions, but they do not trust them completely — people accept that weather forecasters are sometimes wrong about the weather. Still, the weather reports give us a pretty good idea of what to expect — and that's better than nothing! By the same token, climate models may not be very trustworthy at present, but they can help us imagine what future climate may be like and help us design contingency plans based on the scenarios they predict.

Whether global warming actually occurs as predicted, it is important for people to be knowledgeable about what the future could hold. Even a one- or two- degree temperature change could have significant implications for humanity. This is why The Ohio State University is preparing educational materials for teachers, students, and the public. In addition to the Global Climate Change Scenarios describing potential impacts on the Great Lakes, Sea Grant and the National Science Foundation (NSF) support the development of curriculum activities for secondary schools. Funds from the Eisenhower Program and NSF support teacher enhancement workshops in Ohio and throughout the United States. These efforts help to assure that future decision makers will understand climate change and the possible effects of continued global warming on the Earth system.

Although the global warming debate can be difficult to follow at times, people should keep in mind the fact that our questions about the Earth's physical processes have always evolved faster than our understanding. As our computers become more powerful and scientists' knowledge of Earth systems grows, chances are we will develop more reliable climate models. The dilemma is that decisions need to be made *now* if we want to address the future problems that may be associated with global warming.

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The *Global Change in the Great Lakes Scenarios* were prepared by the Ohio Sea Grant College Program (grant NA90AA-D-SG496, project E/AID-2) in cooperation with The Ohio State University's School of Natural Resources and Department of Educational Studies. Barbara K. Garrison and Arrye R. Rosser, Series Editors. Rosanne W. Fortner, Project Director.

For information about the scenarios or global warming, contact the Ohio Sea Grant Education Program, The Ohio State University, 29 W. Woodruff, 059 Ramseyer Hall, Columbus, OH 43210, 614/292-1078. To place an order, send $6 (or $9 if ordering from outside the U.S.), in U.S. dollars, to Ohio Sea Grant-Publications, The Ohio State University, 1314 Kinnear Road, Columbus, OH 43212-1194, 614/292-8949. Make checks payable to The Ohio State University.

GLOBAL CHANGE
EDUCATION

Technology Fact Sheet

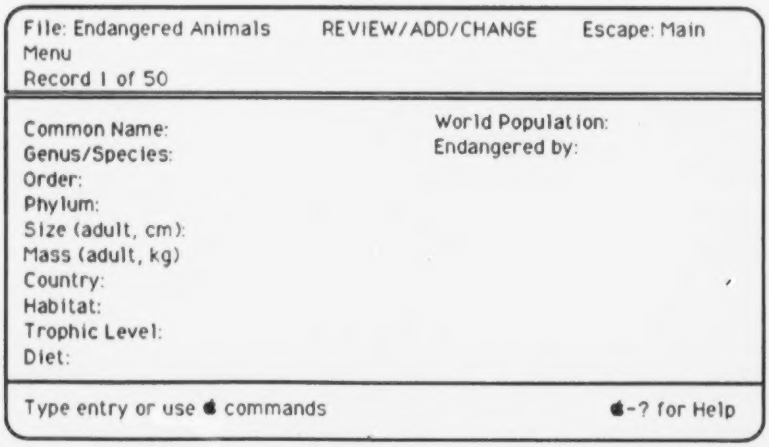
Creating an Appleworks Database

A database is a filing system. You can create your own personalized files using data you collect yourself or find in reference books. By identifying in advance what uses you will have for your data, you can enter information in a form that is most valuable for your global change studies.

Endangered species lists are useful in database form, for example. Make a list of important information about such species for the purposes you have in mind. Younger children, for example, may want to sort animals by body cover, number of legs, bones or no bones, life expectancy, number of offspring, habitat, food, and common name. They could then pull out all the sea animals with bones, or they could arrange the animals in order by number of offspring. Older students may include scientific name, phylum, specifics of habitat, continent, predators, reason for endangerment, and the like. The database should have any category of information that you will want to sort numerically or alphabetically, and any category you may want to look at by itself (e.g. all insects).

PROCEDURE:

1. Boot the startup disk and Appleworks Program Disk. When you have entered the date as the screen directs, the Main Menu will appear. Select "Add files to the desktop." [Return]
2. The next menu says "Get files from ---." Put an initialized disk in Drive 2. Move the cursor to "Make a new file for the --- Data Base." [R]
3. Type a name for your new file using 15 or fewer characters. [R]
4. The next screen allows you to establish the categories of information you want to file. On the right side are the things you are allowed to do. To get HELP at any time, type (in sequence and holding keys down) -shift-?
5. Delete the line that says Category 1 and replace it with the first type of information you will file, such as Common Name. [R] Add other categories, with [R] after each. You may enter up to 30 categories.
6. When all your categories are entered, press ESC. You can now begin to enter data in Record 1 of your filing system. It might look like the one at the bottom of this page.
7. Enter all the information you can about each plant or animal. Leave blanks if you need them. [R] after each entry and again at the end of the complete Record. To change what you have typed in any category, use the arrows and delete key, then retype.
8. To save your work at any time, press S. You can go back and change your saved files at any time.



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File: Endangered Animals        REVIEW/ADD/CHANGE       Escape: Main
Menu
Record 1 of 50

Common Name:                                   World Population:
Genus/Species:                                 Endangered by:
Order:
Phylum:
Size (adult, cm):
Mass (adult, kg)
Country:
Habitat:
Trophic Level:
Diet:

Type entry or use  commands                                  -? for Help
```

Example of an empty Record in an Appleworks database

Ways to look at your files

1. Appleworks displays files in two ways. The example on the front of this sheet is the Single Record Layout. You can only add to or change your records in this format. The other layout is Multiple Record. You see only the first few categories of information, but for many records. To go from one type of layout to the other, use **-Z** (for Zoom).
2. To arrange your file, put the cursor on the first letter of the category to be arranged, such as Phylum. Type **-A** and select the method of arranging (A to Z) [R]. Zoom to the Multiple Record layout and you will see all the phyla in alphabetical order.
3. To work with only one group of animals at a time, you can select the Records you want. Type **-R**, then choose the category to be searched. Suppose you want all endangered marine mollusks in the United States. You would select Phylum then Equals then the word to be matched: Mollusca. Then select AND, matching it with Habitat Contains Marine, AND Country Equals USA. If your database has many records, you can develop some interesting lists of organisms with similar characteristics.

Printing your files

Appleworks files can be printed in two ways. LABEL format looks like address labels, with categories listed below each other like this:

Common name: Kirtland's Warbler
Scientific name: *Dendroica kirtlandii*
Range, Habitat: N-Central US, Canada; jack pine forests
Endangered by: Forest habitat loss

You can select the categories you want to print and which line you want them to appear on.

The other print format is TABLE format. It looks like the Multiple Record screen, but the categories have all their letters and only certain ones are selected. You might want to list, for example, this table:

Vertebrate	Freshwater	Blue Pike	Lake Erie
Vertebrate	Freshwater	Paddlefish	Ohio River
Vertebrate	Marine	Menhaden	Atlantic O.
Vertebrate	Marine	Yellowfin	Pacific O.

(This list was arranged alphabetically by habitat, and only Vertebrates were selected.) To begin the layout process, select **-P** for Print.

LABEL Formatting:

1. Select "Create a new Labels format." [R] Give your format a descriptive name of 15 characters or less. [R]
2. The list of all your categories will appear down the screen. Delete the ones you don't want with **-D**. To get one back, use **-I** for insert, and you'll get a list of choices. To rearrange the categories, put the cursor on the first letter of one you want to move. Hold the down and use the arrows to put the cursor in a new place. Save your format with **-S**.

TABLE Formatting:

1. Select "Create a new Tables format." [R] Name your format.
2. Categories will appear across the screen. Delete the ones you don't want, as above.
3. Look at each category and decide how many spaces long it needs to be to serve its purpose. To change a column width, put the cursor on the category, hold down, and use the arrows to add or subtract spaces. See an Appleworks manual for other options. Save.

When your format is complete, select **-P** again, choose the printer you are using, and request a copy. [R]

References

Anderson, Christopher L. Designing a zoo-based endangered species database. Science Activities, Nov/Dec, 1989. 14-18.

Anderson, Christopher L. Strategies for introducing databasing into science. Journal of Computers in Mathematics and Science Teaching 9(2), 1989.

Endangered Species Database (commercial). Order from Society for Visual Education, Inc., Dept. VR, 1345 Diversey Pkwy, Chicago, IL 60614-1299 ($129 in 1989)

Micik, J.M. et al. Using a microcomputer database in tree identification. Science Activities 23(2): 14-17, 1986.

Global Change Education Technology Fact Sheets are produced by the School of Natural Resources and Department of Educational Studies at The Ohio State University. For information about other technology fact sheets, contact Dr. Rosanne W. Fortner, OSU School of Natural Resources, 2021 Coffey Road, Columbus, OH 43210. Phone 614/292-2265. FAX 614/292-7162. (4/91)

GLOBAL CHANGE
EDUCATION

Technology Fact Sheet

INTERACTING WITH AN ON-LINE DATABASE: EcoNet

On-line databases are ready-to-use databases accessible to anyone with a telephone line, a modem, a computer, and any computer software which is designed for the computer and able to interact with the modem. If this equipment is available to you, and if everything is set-up properly, you can simply use the telephone line to access any on-line database. All you need to know at this point is a telephone number, some parameter settings for the modem, and some knowledge about the database you are accessing.

EcoNet

A good way of learning how to access an on-line database is to experiment with one during an actual live session. As an example, consider **EcoNet**, the International Computer Network for Information related to Environment and Education. With **EcoNet**, you can access information pertaining to education and the environment by electronic mail, news, or conferences. To do this, simply go through the steps provided for you in the set-up and interaction procedures.

SET-UP PROCEDURE:

1. Make sure everything is turned on and is ready to go.
2. Change the modem's parameters to meet the on-line database's specifications. For **EcoNet**, the parameters are as follows:
   - Full Duplex
   - 7 Data Bits
   - 1 Stop Bit (2 stop bits for 300 baud)
   - Odd Parity
   - Other parameters (such as baud rate) depend on the particular modem being used.
3. With your modem dial the telephone number of the on-line database. Also, be aware that some on-line databases have different telephone numbers for different modem speeds (baud rates). For **Econet**, the phone numbers are:
   - **Cleveland, OH** (area code 216):
     575-1658 (300/1200 Baud)
     771-6480 (2400 Baud)
   - **Columbus, OH** (area code 614):
     463-9340 (300/1200 Baud)
     461-9044 (2400 Baud)

NOTE: Some on-line databases require access information such as an access code, a login name, or a password. EcoNet requires a login code and a password in order for their system to be used. For EcoNet's login information, contact:

Institute for Global Communications
3228 Sacramento Street
San Francisco, CA 94115
(415) 923-0900.

INTERACTION PROCEDURE:

1. After dialing **EcoNet**, you should see the word "CONNECT" on your computer monitor (if you don't see "CONNECT", try dialing again or check your equipment). After the "CONNECT" prompt do the following:

For (1200 Baud):
- Press <RETURN> twice.
- After the "Terminal =" prompt, hit <RETURN>.
- After the "@" prompt, **enter:** 408346 and hit <RETURN>.

For (2400 Baud):
- Type @ and press <RETURN>.
- After the "Terminal =" prompt, hit <RETURN>.
- After the "@" prompt, **enter:** 408346 and hit <RETURN>.

Before you continue, be sure to use lower case letters!

Now you are ready to enter your login access code. Following the "login: (? for help):" prompt, enter your login access name. After the "Password: (? for help):" prompt, enter your password (xxxx's will appear as you enter it).

2. You should now see a "Terminal = generic (press <RETURN> or enter new terminal type):" prompt. After this prompt, press <RETURN>.

3. You should now see the following options: **(c)onf (h)elp (m)ail (s)etup (u)sers bye.** You can try any of these options by entering their corresponding letters and pressing <RETURN>. For now, however, **enter:** c and press <RETURN> to get into the conferences.

4. **Enter:** ? and press <RETURN> for the list of available commands. **You should now see:**

```
g - go to conference
l - list conferences
v - visit the next regular conference
q - quit out of conf
h - provide more help
m - conference list maintenance
```

5. **Enter:** l and <RETURN> for a conference list.
   - Press <RETURN> for EcoNet after the "Network: (a)ll, (o)ther, etc." prompt.
   - After the "Enter name, keyword, etc." prompt, press <RETURN>.
   - Following the "Do you want: a (s)hort, (m)edium, or (l)ong listing etc." prompt, **enter:** s and press <RETURN> for a short listing of conferences. (If your modem, software, and computer are properly communicating with one another, you should see a legible list of conferences).

6. Before you select a conference, you must press <RETURN> to quit the list of conferences. Now you can select any conference from the list you generated. As an example, consider the conference called 'en.wildlife'. After the "Conf?" prompt, **enter:** en.wildlife and hit <RETURN>.

7. On the monitor, you should see how many unread topics and responses there are for the en.wildlife conference. While you are in the conference mode, any time you enter a '?', you will be given the list of command options for conferences. **Enter:** ? and press <RETURN> to view the list. **You should now see:**

```
- To read a topic, type its number.
- To read a response, type the topic number, then a period,
  then the response number (for example, 14.5 displays re-
  sponse 5 of topic 14).

Basic Commands (use the 'help' command for more extensive
help).

b/f  (b)ackward / (f)orward one page.
u    show next (u)nread message.
t    show next unread (t)opic.
v    (v)isit next regular conference.
q    (q)uit from conf.
i    show (i)ndex page --- (all topics).
c    (c)apture commands (e.g. kermit).
```

8. For this session, **enter:** i and <RETURN> for an index of all the topics in the en.wildlife conference.

9. After you have looked over the various topics in the en.wildlife conference, you can select any topic at all by using the basic commands that you have just listed. You will most likely use b, f, u, and t. Or, you can type the number of the topic you wish to view followed by pressing <RETURN> (remember, from #7 on the previous page, you were given the total number of topics in the en.wildlife conference. So if there are 123 topics, the numbers you use to select a topic must be from 1 to 123).

10. You can also visit the next conference via the **v** command. If you do this, you might want to get an index of all the topics in that conference since it will be different than the en.wildlife conference.

11. If you are finished viewing conferences, you can exi the conference mode by typing 'q' and pressing <RETURN> after the "Conf?" prompt.

12. You should now see the EcoNet commands: **(c)onf (h)elp (m)ail (s)etup (u)sers bye.**

NOTE: At some other time, you might want to continue by selecting any of these commands. To get a printout of the information you have acquired, you need to be familiar with your modem and the software you are using, so consult those manuals.

For this session, however, **enter:** bye and press <RETURN>.

You have just successfully interacted with an on-line database!

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A FACT SHEET

SEA LEVEL RISE

Factors Affecting Sea Level

Changes in the level of the world's seas have been the focus of considerable debate. The level of the seas has, however, fluctuated throughout the history of Planet Earth. Geologic and climatic factors influence sea level. Rapid plate movements or glacial melting result in a sea level rise. Glaciation or tectonic quiet result in a sea level drop. Geological factors are, however, usually slow processes and are unlikely to greatly affect sea level rise in an accelerated manner.

Climatic factors are quite different. There are two ways in which the world's climate affects sea level: first, by disturbing the balance between water locked up in glaciers and in liquid form, and second, by changing the temperature of the oceans.

As the temperature of water increases, the volume also increases. This fact has been known for a long time, but only recently has it been applied to the seas. Even if the glaciers did not melt as a result of global warming, the simple increase in global temperature would cause an increase in the volume of the world's seas and consequently a rise in sea level. While it is true that it would take hundreds of years to warm the entire ocean system of Earth, the upper layers would be warmed and could cause as much as a one meter rise in sea level in just 20 years.

History of Sea Level Rise

During the height of the last major ice age (12,000-20,000 years ago) sea level was about 100-150 meters lower than it is today because so much of the planet's water was in the form of ice in glaciers on land. Temperature and sea level rose to today's levels during the warm interglacial periods. From the end of the last ice age to about 6,000 years ago, the seas rose at a rate of about one centimeter per year.

Tidal gauges designed to measure sea level have been used at various locations around the world for about the last 100 years. Scientists who have analyzed the measurements of these gauges have determined that during the last century worldwide sea level has risen 10-15 centimeters.

The Greenhouse Effect and Sea Level Rise

Human impact on the earth's temperature may upset the stability that has existed between climate and sea level. We may be causing the planet to warm at a rate far too fast to allow for the natural evolution of systematic changes.

The main problem appears to be a dependence on the burning of fossil fuels. The burning of fossil fuels releases carbon, stored for millions of years, into the atmosphere. Carbon dioxide (CO_2) has been identified as the major contributor to the warming of Earth. The National Academy of Science has estimated that doubling the amount of CO_2 in the atmosphere could result in a 1.5-4°Celsius increase in the world's temperature.

As an illustration consider the following:

1. The oceans of the world have a volume of 329,000,000 cubic miles.
2. Assume an average global ocean temperature of 20° Celsius.
3. Assume that only 10 percent of the oceans total volume (32,900,000 cubic miles) would warm just 1°Celsius to 21°Celsius as a result of global warming.

If assumptions 2 and 3 above were realized the total volume of the world's oceans would increase 6,580 cubic miles. In more everyday terms, 1 cubic mile of ocean contains 39,479 gallons of water, therefore, a 6,580 cubic mile volume increase means 260 million more gallons

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N.J. Smith-Sebasto. 1991

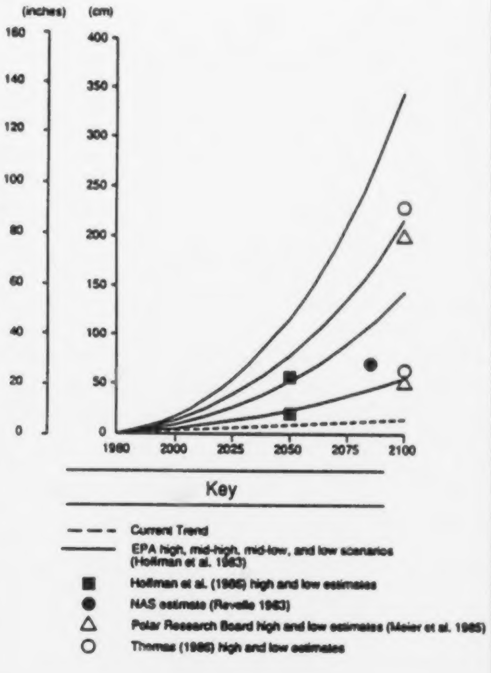
of water. The melting of polar ice caps could be 2-3 times the effect of thermal expansion.

Most of the planet is water, with land above sea level occupying only a small portion of the globe. Any significant rise in sea level is cause for alarm, especially considering the amount of development, both residential and industrial, near coastlines.

Effects of Sea Level Rise

A sea level rise would have numerous consequences. Among them are: 1) inundation of shorelines; 2) salt intrusions; 3) increased erosion, and 4) increased flooding. Those areas currently at or near sea level, such as Miami, Florida; Everglades National Park; New Orleans, Louisana; and others could become our first underwater cities and parks.

Global Sea Level Rise Possibilities



Source: "Greenhouse Effect, Sea Level Rise and Coastal Wetlands." EPA. July 1988. EPA-230-05-86-013, Office of Policy, Planning and Evaluation, Washington, D.C. 20460.

Freshwater marshes and wetlands, some of which are considered to represent levels of biological diversity and importance unsurpassed in the world, would succumb to increases in saltiness of their waters. Aquifers supplying groundwater to coastal cities could have their freshwater increasingly replaced by salt water. Finally, those areas not normally subjected to extreme flooding, such as Sacramento, California, and Baton Rouge, Louisana, could find themselves beach front properties.

Suggested Reading

Barth, M. and J. Titus. 1984. *Greenhouse Effect and Sea Level Rise.* Van Nostrand Reinhold Company.

Good, J.W. *Greenhouse Warming and Sea Level Rise.* College of Oceanography, Oregon State University, Corvallis, OR 97330-5503.

Hoffman, J.S., D. Keyes, and J.G. Titus. 1983. *Projecting future sea level rise.* U.S. GPO #055-000-236-3. Washington, D.C.: Government Printing Office.

Hoffman, J.S., J.B. Wells, and J.G. Titus. 1986. *Future global warming and sea level rise in Iceland Coastal and River Symposium*, edited by F. Sigbjarnarson. Rekjavik: National Energy Authority.

Meier, M.F., et al. 1985. *Glaciers, Ice Sheets and Sea Level: Effects of a CO_2-Induced Climatic Change.* Washington, D.C.: National Academy Press.

Revelle, R. 1983. *Probable future changes in sea level resulting from increased atmospheric carbon dioxide in changing climate.* Washington, D.C.: National Academy Press.

Thomas, R.H. 1986. "Future sea level rise and its early detection by satellite remote sensing" In J.G. Titus (ed.) 1988. *GreenhouseEffect, Sea Level Rise and Coastal Wetlands. EPA.* Washington D.C.: Office of Policy, Planning and Evaluation.

GLOBAL CHANGE EDUCATION

Technology Fact Sheet

Getting to Know CDIAC

The Carbon Dioxide Information Analysis Center (CDIAC), located within the Environmental Sciences Division of Oak Ridge National Laboratory, has been in operation since 1982. CDIAC provides information support to the international research, policy, and education communities for evaluation of complex environmental issues associated with elevated atmospheric CO_2, including potential climate change. CDIAC activities include obtaining and evaluating data, articles and reports; producing digital numeric data and computer model packages (NDRs and CMPs); distributing CO_2-related reports; and producing the newsletter *CDIAC Communications*, with a world-wide distribution of over 5,000 subscribers in 151 countries.

CDIAC is funded by the U.S. Department of Energy (DOE) to support its Carbon Dioxide Research Program (CDRP). The goal of the CDRP is to develop sound scientific information for policy formation and governmental action in response to changes of atmospheric CO_2. The thrust of the CDRP during the past decade has been to (1) elucidate the processes that control the global carbon cycle and provide predictions of future atmospheric CO_2 change, (2) develop data and models of the processes by which changes in the Earth's radiative balance may change climate at global and regional scales and predict rates of potential climate change, and (3) develop the data and models required to define and predict the combined effect of climate and CO_2 on plants, crops and ecosystems.

The mailing address for the Program is:

CDIAC, Bldg. 1000
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6335

TRENDS'90

To provide ready access to data and information critical to the greenhouse effect and to global-warming issues, CDIAC is preparing a new document, *TRENDS '90: A Compendium of Data on Global Change*. *TRENDS* is intended to provide a quick source of frequently requested data along with summaries of recent "trends" in these data. The presentation of the data in *TRENDS* differs from traditional scientific publications or even CDIAC's NDPs. For *TRENDS*, the editors have adopted a two-page format for presenting the data. Each spread of two pages deals with a different topic. Upon opening *TRENDS*, the reader will find critical background information, graphical presentations, and a brief summary of the data on the left-hand page and a tabular listing of the data and a list of references on the right-hand page. The format is intended to provide the general user with all the needed information on two facing pages.

CDIAC plans to publish *TRENDS* on an annual basis. The inagural issue of *TRENDS* includes historical and modern records of atmospheric CO_2 concentrations, atmospheric CH_4 concentrations, and CO_2-emission estimates from fossil-fuel burning. Future issues of *TRENDS* may include additional types of data, such as concentrations of other trace gases, land-use data, oceanographic data sets, long-term temperature and precipitation records, and computer-model output (i.e., the results from general circulation models, vegetation models, CO_2- and CH_4-emission models, ocean models, and carbon-cycle models). The direction and format of future issues will be largely determined by feedback received on the first issue. The editors encourage comments on *TRENDS* and suggestions on data and format for future issues.

CDIAC Numeric Data Packages and Computer Model Packages

Unless otherwise noted, all data sets are available on 9-track magnetic tape and on 3.5- or 5.25-in. floppy diskette, IBM PC format.

ATMOSPHERIC CO_2 CONCENTRATIONS - MAUNA LOA OBSERVATORY, HAWAII, 1958-1986
C.D. Keeling
Scripps Institution of Oceanography
CDIAC NDP-001/R1 (Rev. 1986)

TREE-RING CHRONOLOGY INDICES AND RECONSTRUCTIONS OF PRECIPITATION IN CENTRAL IOWA, USA
T.J. Blasing and D.N. Duvick
Oak Ridge National Laboratory
CDIAC NDP-002 (1984)

PRODUCTION OF CO_2 FROM FOSSIL-FUEL BURNING
R.M. Rotty and G. Marland
Oak Ridge Associated Universities
CDIAC NDP-006 (1984)

GLOBAL PALEOCLIMATIC DATA FOR 6000 B.P.
Thompson Webb III
Brown University
CDIAC NDP-011 (1985)

GLOBAL AND HEMISPHERIC ANNUAL TEMPERATURE VARIATIONS BETWEEN 1861 AND 1988
P.D. Jones, T.M.L. Wigley, and P.B. Wright
University of East Anglia
CDIAC NDP-022/R1 (Rev. 1990)

AVERAGE TOTAL SNOWFALL DATA FOR SELECTED U.S. STATIONS
National Climatic Data Center
National Environmental Satellite, Data, and Information Service
CDIAC NDP-031 (1989)

GLOBAL SURFACE-AIR TEMPERATURE VARIATIONS: 1851-1984
P.D. Jones, S.C.B. Raper, P.M. Kelly, and T.M.L. Wigley
University of East Anglia
CDIAC NDP-003/R1 (Rev. 1986)

GROWTH AND CHEMICAL RESPONSES TO CO2 ENRICHMENT - VIRGINIA PINE
(*Pinus virginiana Mill.*)
R.J. Luxmoore, R.J. Norby, E.G. O'Neill, and D.G. Weller
Oak Ridge National Laboratory
J.M. Ells and H.H. Rogers
North Carolina State University
CDIAC NDP-009 (1985)

CLIMATIC DATA FOR NORTHERN HEMISPHERE LAND AREAS: 1851-1980
R.S. Bradley
University of Massachusetts
P.M. Kelly, P.D. Jones, and C.M. Goodess
University of East Anglia
H.F. Diaz
National Oceanic and Atmospheric Administration
CDIAC NDP-012 (1985)

ANNUAL AND SEASONAL GLOBAL VARIATION IN TOTAL OZONE AND LAYER MEAN OZONE, 1958-1986
J.K. Angell anf J. Korshover
Environmental Research Laboratories
National Oceanic and Atmospheric Administration
W.G. Planet
National Environmental Satellite, Data, and Information Service
CDIAC NDP-023 (1987)

MONTHLY MEAN PRESSURE RECONSTRUCTIONS FOR EUROPE (1790-1980) AND NORTH AMERICA (1858-1980)
P.D. Jones, T.M. Wigley, and K.R. Briffa
University of East Anglica
CDIAC NDP-025 (1987)

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GLOBAL CHANGE
EDUCATION

Technology Fact Sheet

CD-ROM

What is it? Compact disc is the generic name of a group of read-only optical disc formats developed by Sony and Philips in 1980. The most common type is a 12-cm rigid plastic platter, but a 9-cm version was introduced in 1987. The discs have a reflective metal layer covered with a protective coating, all on a rugged base material that permits relatively casual handling. The technology's earliest application was in digitized sound, the popular "CD" offers a super high-fidelity audio recording capability compared to phonograph records and magnetic tape.

How does it work? The Compact Disc-Read Only Memory (CD-ROM) uses CD technology to record, store, and access machine-readable, computer-processible data. Digitally coded information is recorded as a series of microscopic pits and adjoining spaces, all arranged in spiralling tracks. A standard size CD-ROM can have up to 2000 tracks per inch, compared to 150-300/inch on floppy disks. A CD-ROM has 540 megabytes of storage capacity for digital information. Recording is done on both sides of the disc· if audio is combined with text and graphics, however, the data capacity is decreased.

CD-ROMs require a special disc drive or "reader" that may be installed internally or externally on a personal computer. The CD reader does not actually release usable information from the disc. There must be software that reads the material, and documentation that supports it, just as floppy disk technologies have. In some cases the software is included on the CD, but in other cases a floppy disc contains the access program or a hard copy manual describes the uses and interpretation of the material.

Multiple reader units are available, as are multi-disc changers that resemble juke box retrieval systems. Access time between discs is a maximum of six seconds at this writing.

How is it used? More and more data-generating organizations are seeing the CD format as an efficient one for handling large amounts of information, and for subdividing mainframe and magnetic tape datasets into a form that can be more easily accessed and transmitted. CD-ROMs are a form of electronic publishing. Their applications consist mainly of (1) private distribution of controlled information to selected user groups, and (2) public access to databases and reference services for use by or for sale to interested parties. An example of private implementation is the U.S. Postal Service's ZIP+4 product that replaces a mainframe-based zip code retrieval system. Ford, Chrysler and others have developed CD-ROM auto parts catalogs to distribute to dealers.

Since the technology began, however, the focus of CD-ROMs has been reference service. By the end of 1989 there were over 500 published databases in this format, and the rate of new discs being introduced has accelerated. Examples include Grolier's Encyclopedia, the Guinness Disc of World Records, and various versions of the Bible. In libraries some on-line data searches have been replaced by CD-ROM. Disc producers are now reaching out to owners of home computers, offering more consumer-oriented materials such as telephone books and dictionaries. Anticipating more use of the technology by teachers, Dr. Mary Budd Rowe, former President of the National Science Teachers Association, completed a project that resulted in elementary science curriculum materials being stored for distribution on a CD-ROM.

The remainder of this publication lists some CD-ROMs available for use in global change education. The list is not intended as an endorsement of the products, only as a guide to the range and sources of materials available in 1991.

For additional information, consult:

CD-ROM End User, monthly magazine available at computer stores and larger news stands.

Saffacy, W. July-Dec. 1990. CD-ROM: A survey of technology, products, and applications. *Library Computer Systems and Equipment Review* 12 (2).

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NASA's Science Sampler I and II

Sampler I contains over 800 images of Uranus from the Voyager spacecraft and Sampler II contains scientific data on astronomy, solar-terrestrial disciplines, lands, oceans, etc.

System: IBM or Macintosh.
Price: $25.00 for the set ($35.00 for international orders).
Contact: LASP, Campus Box 392, University of Colorado, Boulder, CO 80309. Attn: Randy Davis.

Down to Earth! Close-ups of Nature

Nearly 1,000 color and monochrome images for use in desktop publishing, education, etc. Categories include: Marine environment, environmental impact, landscapes and food.

System: Macintosh.
Price: $249.00
Contact: Wayzata Technology. Tel: 612/447-7321 or Toll Free: 800/735-7321.

1:2,000,000 - Scale Digital Line Graph Data

This CD ROM contains data for all 50 states, organized into 21 geographic regions. The data are from late 1979 to the present. Categories of data include: Political boundaries, adminstrative boundaries, streams, water bodies, hypsography, roads and trails, railroads and cultural features.

System: IBM or compatible.
Price: $28.00
Contact: U.S.G.S National Mapping Division, Earth Science Information Center, 507 National Center, Reston, VA 22092. Tel: 703/648-6045 or Toll Free: 800/USA MAPS.

Out of This World!

More than 160 images of stars, planets, nebulae, astros and shuttles.

System: Macintosh II.
Price: $249.00
Contact: TSUNAMI Press, 275 Rt. 18, East Brunswick, NJ 08816.
Tel: 201/613-0509; FAX: 201/238-3053.

The World Almanac and Book of Facts

Over 1 million up-to-date facts that cover such topics as science, technology, economics, noted personalities, consumer information, sports, and much more.

System: Macintosh.
Price: $59.00
Contact: Discovery Systems.
Tel: 614/761-2000; FAX: 614/761-4258.

World Weather Disc

Contains massive meteorological data base that describes the climate of the Earth today and during the past few hundred years. The disc includes many of the soughtafter meteorological data sets held in the archives of the National Climatic Data Center and the National Center for Atmospheric Research. The data sets offer information on a wide variety of questions ranging from the nature of global temperature trends to inquires about the weather at specific locations around the world.

System: IBM.
Price: $295.00
Contact: CD-ROM Inc. (as above)

NOAA LINC

Contains the bibliographic records of 22 NOAA libraries and information centers.

System: IBM or compatible.
Price: Unknown.
Contact: The Library Corporation, P.O. Box 40035, Washington, DC, 20016.
Tel: 800/229-0100.

Comet P/Halley

18 discs with compressed images; 5 discs with mixed data, 3 discs with spacecraft data; descriptions of software and images on discs.

System: IBM AT class PC or Macintosh.
Price: Free to NASA and other space agencies and universities.
Contact: International Halley Watch.

The USA Factbook

An electronic almanac of the 50 United States and its territories. Includes information about vital statistics, economies, transportation, geography, traditions, etc. Published annually.

System: Macintosh.
Price: $139.00
Contact: Wayzata Technology.
Tel: 612/447-7321 or Toll Free: 800/735-7321.

Alaskan Marine Contaminants Database

This disc contains data collected from 35 studies of the marine waters of Alaska and includes information about the areas of study, contaminants, and the quality of the data. The database allows oceanographic chemists to access data from the past decade.

System: IBM PC/XT/AT/386/PS2 or compatible.
Price: Written request required.
Contact: Dr. Jaweed Hameedi, NOAA/OAD, Alaska Office, 222 West 8th Ave., Anchorage, AK 99513.

Gloria Imagery and Bathymetry.

GLORIA imagery and bathymetry from the U.S. Exclusive Economic Zone (EEZ) off Washington, Oregon and California is now available on CD-ROM. The GLORIA imagery extends from 40 to 49 degrees North Latitude while the bathmetry extends from 30 to 49 degrees North Latitude.

System: IBM PC computer under DOS with compatible CD-ROM reader. (If other than an IBM-DOS system is used, appropriate software will be necessary to read the ISO 9660 formatted discs.)
Price: None specified.
Contact: Books and Open-File reports Section, U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225.

Geo Ref

Geo Ref is a computerized bibliographic data base containing the information from the Bibliography and Index of Geology, Bibliography of North American geology, Bibliography and Index of Geology Exclusive of North America, Bibliography of Theses in geology, and Geophysical Abstracts. There are more than 1.6 million records in the data base, from 1785 to present. Each record in the data base is a reference to a journal article, book, dissertation, conference proceeding or map. The records contain information necessary to describe the item, such as author, title and source publication.

System: Ms-DOS compatible computer with 640 RAM, a hard disc, and a CD-ROM player. Minimum software required are MS-DOS CD-ROM Extensions or MSCDEX, and MS-DOS or PC-DOS 3.1.
Price: $2,800 per year.
Contact: SilverPlatter Information, Inc. One Newton Executive Park, Newton Lower Falls, MA 02162-1449.

Environmental Data Disc

This disc contains 70 Data Stacks. It has critical numerical data bearing on a number of environmental challenges. It contains: General environmental data from the World Resources Institute, Global Change Climate Data from the Carbon Dioxide Information Analysis Center, United States temperature and precipitation data from 1918-1987 bearing on the Greenhouse Effect, Worldwide food and agricultural data, World demographic data, Atmospheric ozone data from 106 stations across the world and sample energy, economic and trade data for the industrialized countries.

System: Macintosh computer, CD-ROM Drive, Hypercard 2.0 (included), System 6.07 (included) or 7.0.
Price: $149.00
Contact: Environmental Data Disc, PEMD Education Group, P.O. Box 39, 178 Vine Street, Cloverdale, CA 95425.
Tel: 707/894-3668.

GeoMedia

Teaching Earth Science through new technology. Textual and visual information on water cycle, earthquakes and maps.

System: Macintosh.
Price: Free demo.
Contact: InterNetwork, Inc.
411 Seventh St, Del Mar, CA 92014.

Bathymetry of Monterey Bay Region

High Resolution bathymetry and selected geoscience data for the Monterey Bay region.

System: DOS format.
Price: Call for educator's price.
Contact: U.S.G.S. Department of the Interior, 810 National Center, Reston, VA 22092.

GLORIA (East Coast Hurricane)

Disk A: image maps of the hurricane along the east coast of the USA.
Disk B: Data files.

System: DOS format.
Price: Call for educator's price.
Contact: U.S.G.S. Department of the Interior, 810 National Center, Reston, VA 22092.

Joint Earth Sciences

Major portions of the USA are surveyed using Side-Looking Airborne Radar (SLAR) between the years 1980-1988.

System: DOS format.
Price: Call for educator's price.
Contact: U.S. Geological Survey Department of the Interior, 810 National Center, Reston, VA 22092.

Global Ecosystems Database

Major databases on atmospheric data, vegetative patterns, etc.

System: DOS format.
Price: Unknown.
Contact: U.S. EPA., NOAA, National Geophysical Data Center, 325 Broadway, Boulder, CO 80303.

Greenhouse Effect Detection Experiment

Data sets of atmospheric constituents, solar irradiances, Earth radiation, cloud data, and temperatures.

System: IBM or compatibles and Macintosh.
Price: Free.
Contact: Data Management Systems Center, Goddard Space Flight Center, Greenbelt, MD 20071.
Tel: 301/286-9760; Fax: 301/286-3221.

Birds of America: Multimedia

Full text and images on CD-ROM contains Audubons Original 1840 1st Edition Octavio Set with full-text and beautiful full color lithographs. Bird calls from Cornell University Library of Natural Sounds.

System: IBM and MAC.
Price: $95.00
Contact: CD-ROM Inc. 1667 Cole Blvd., Suite 400 Golden, CO 80401.
Tel: 303/231-9373; FAX: 303/231-9581.

Audubon's Mammals: Multimedia

John James Audubon's beautiful, classic mammal prints are now available on multimedia CD-ROM disc. The rare and complete 1840 edition of "Quadrupeds of North America" includes plates in full color and the text, as well as CD quality sounds from Cornell University's Library of Natural Sounds for many of the mammals. One of the leading naturalists of his time, Audubon compiled detailed information about each mammal. This disc is a companion to Birds of America: Multimedia and is ideal for students, history buffs, fine art collectors, libraries and schools.

System: IBM and MAC.
Price: $99.00
Contact: CD-ROM Inc. 1667 Cole Blvd., Suite 400 Golden, CO 80401.
Tel: 303/231-9373; FAX: 303/231-9581.

GEOdisc U.S. Atlas

GEOdisc U.S. Atlas is a CD-ROM geographic database that contains a complete digital representation of the United States at the 1:2,000,000 scale. It includes major highways, waterways, political boundaries, railroads, federal land areas, and hydological districts. In addition it contains a complete place and landmark names file of more than one million entries, each with the appropriate coordinate information to allow it to be placed on the map. Using the Windows/On the World application software program written for the Microsoft Windows 3.0 allows complete interactive vector graphics capability, ability to generate accurate map overlays, ability to display distance, bearing and position information, links to external databases, ability to cut and paste maps to other documents.

System: IBM.
Price: $595.00
Contact: CD-ROM Inc. 1667 Cole Blvd, Suite 400 Golden, CO 80401.
Tel: 303/231-9373; FAX:303/231-9581.

North American Indians

A text/image database on the history of Native Americans. Included are leadership, tribal heritage, religion, family life, and customs.

System: IBM and MAC.
Price: $125.00
Contact: CD-ROM Inc. (as above)

1990 Census Data

The 1990 census data are provided in dBase III format allowing you to use it with any number of third party software programs. In addition, the data are provided by ZIP Code, as well as by tract, place, county, state and the U.S.

System: IBM.
Price: Unknown.
Contact: CD-ROM Inc. (as above)

Environmental Periodicals Bibliography 1972-present

More than 400,000 citations make EPB, from the Environmental Studies Institute of International Academy, the world's most extensive collection of records focused on environmental issues and research.

System: IBM.
Price: Call for annual subscription rate.
Contact: CD-ROM Inc. (as above)

Water Resource Abstracts Volume 1

1967-present. The entire 225,000 abstracts of the USGS on one disc. Advanced software features make this disc of choice for the USGS and any other wsers. A NISC DISC Publication.

System: IBM.
Price: $575.00 Semi-annual updates.
Contact: CD-ROM Inc. (as above)

Electronic Map Cabinet

Electronic Map Cabinet is based on data from more than 300 distinct data bases from four Federal agencies. You can find the place you want to map visually (point and click) by latitude/longitude or by place name. Built in graphics tools let you add text, lines, distance circles and other graphic annotations to your base map. Or you can export your base map in PICT format to your favorite graphics package for further enhancement.

System: MAC.
Price: $189.00
Contact: CD-ROM Inc. (as above)

Wildlife and Fish Worldwide-Volume I

1971-present. More than 200,000 citations from the U.S. Fish and Wildlife Services Wildlife Review and Fisheries Review. Excellent subject coverage, taxonomic, and geographic identifiers as specific as the county, community, lake and stream level make this CD-ROM an excellent choice for the natural resource researcher. Semi-annual updates.

System:IBM.
Price: $695.00
Contact: CD-ROM Inc. (as above)

Population Statistics

Full range of population and housing characteristics from the 1980 census for states, metro areas, counties, places of 10,000 or more and other areas. Also Census Bureau population estimates by age, race, and sex for counties through 1984; population and per capita income estimates for 40,000 + areas for 1980 and 1986; and census population projections through 2010. SEARCHER search and retrieval software included with the disc searches the databases, creates and prints reports, generates files for use with other computer programs.

System: IBM.
Price: $745.00
Contact: CD-ROM Inc. 1667 Cole Blvd., Suite 400 Golden, CO, 80401/
Tel: 303/231-9373; FAX: 303)231-9581

Space Science Sampler: Volumes 1-2

Volume 1 includes 800 of the best Voyager images of Uranus, its rings and moons. Space and Earth science data collected from scientists during a NASA project called the PDS Interactive Data Interchange. Volume 2 contains a wide variety of space science data collected during the Interactive Data Interchange in 1986. Both volumes were produced by NASA and the University of Colorado. The discs conform to ISO 9660 Standard, Level 1, for CD-ROM interchange.

System: IBM.
Price: $39.00
Contact: CD-ROM Inc. (as above)

Voyages to the Outer Planets Vol. 1-12

This is a 12 disc set with over 25,000 images returned by NASA's twin Voyager Spacecraft during their journeys to Jupiter, Saturn, Uranus and Neptune. Software included for image display for Macintosh with EGA/VGA or better.

System: IBM.
Price: $99.00
Contact: CD-ROM Inc. (as above)

Aquatic Sciences and Fisheries

The ASFA database contains citations, abstracts, etc. from leading journals and other publications. Coverage includes biological, ecological, social, economical, and technical aspects of marine, freshwater and brackish environments.

System: IBM X/T/AT/PS2 or compatible.
Price: $2,250 for current subscription.
Contact: Cambridge Scientific Abstracts.

Acid Rain

A selection of more than 100 Canadian federal and provincial documents, many in French and English. There are also over 6,000 images in the two-disk set.

System: IBM XT/AT/386/PS2 or compatible.
Price: Free to educational institutions.
Contact: University of Vermont, Bailey/Howe Library, Burlington,
VT 05405-0036. Attn : Albert Joy.
Tel: 802/656-8350.

Natural Resource Metabase

An integration of more than 45 different U.S. government databases covering endangered species, resource development, wetlands, ecosystems, Pacific islands, etc.

System: Unknown.
Price: $595.00 per year.
Contact: National Information Services Corporation.

Wildlife and Fish Worldwide-Volume 1

Citations from the U.S. Fish and Wildlife Service's Wildlife Review and Fisheries Review. Over 200,000 in-depth records of taxonomic and geographic identifiers.

System: Unknown.
Price: $695.00 per year.
Contact: National Information Services Corporation.

1989 Toxic Release Inventory

The complete National 1989 Toxic Release Inventory and Hazardous Substances Fact Sheets containing reference materials on the health and ecological effects of the regulated substances.

System: PC.
Price: $28.00
Contact: Government Printing Office, N. Capitol and H Streets, NW, Washington, DC 20401. Tel: 202/783-3238.

Polar Pac

A database of international polar regions. Holdings of 34 libraries in 15 countries are included. Over 85,000 bibliographic records and over 156,000 call numbers are provided.

System: IBM PC/XT/AT/386 or compatible.
Price: $250.00
Contact: Western Library Network.
Tel: 206/459-6518; FAX: 206/459-6341.

Pacific Ocean Temperature and Salinity Profiles

Over 1.3 million Pacific Ocean temperature-depth and salinity-depth profiles taken from 1900 and 1988.

System: IBM PC/AT or compatible.
Price: Call for educator's price.
Contact: National Oceanographic Data Center, 1825 Connecticut Ave., N.W., Rm. 404, Washington, DC 20235. Attn: Richard Abram. Tel: 202/673-5591.

Life Sciences Collection

The LCS contains approximately 5,000 publications from journals, books, monographs, etc. that deal with biological, medical, and agricultural sciences.

System: IBM XT/AT/PS2 or compatible.
Price: $1,750 for current subscription.
Contact: Cambridge Scientific Abstracts.

Mammals: A Multi-media Encyclopedia

Over 700 full-screen color photographs of more than 200 animals, fact boxes, essays, range maps, animal vocalations, movie clips and more. A game and glossary are also included.

System: IBM.
Price: $149.00
Contact: National Geographic Society.
Tel: 201/921-1330 or Toll Free:
800/368-2728; FAX: 301/921-1575.

Agricola

Contains the bibliographic cataloging and indexing records of the National Agriculture Library, from 1985 to the present.

System: IBM PC/XT/AT/PS2 or compatible.
Price: $99.00 one-time purchase, $349.00 annual subscription.
Contact: Quanta Press, Inc., 2550 University Ave. West, Suite 245N, St. Paul, MN 55114. Tel: 612/641-0714.

Earth Science Data Directory (ESDD)

Contains over 155,000 bibliographic records of the aquisitions of four of the U.S.G.S. libraries since 1975.

System: PC.
Price: $350.00 per year
Contact: OCLC Online Computer Library Center, Inc., 6565 Frantz Road, Dublin, OH 43017-0702. Attn: Mary Marshall. Tel: 614/764-6000.

Arctic and Antartic Regions, 1950 - Present

More than 260,000 abstracts and citations from six important databases dealing with the Arctic and Antarctic regions.

System: Unknown.
Price: $795.00 per year.
Contact: National Information Services Corporation.

GLOBAL CHANGE
EDUCATION

Technology Fact Sheet

"Hard copy" Data Sets

Many schools are unable to access on-line information sources, because telephone lines are unavailable or attached to switchboards that make connections difficult, or because long distance calls are not permitted. There are alternative means of accessing many of the databases described in these factsheets, and a call to the agency responsible for each will usually identify an individual who can do a personalized search of materials needed.

There are also many databases that are published in hard copy and may be either entered in computer spreadsheets or used for analyses as is. The following books of data are all paperback, and most are published at regular intervals so they remain up to date.

- Council on Environmental Quality, 1989. *Environmental Trends.* U.S. Government Printing Office, Washington, D.C. Excellent full color graphs of changes in recent decades. Specific to the U.S., so it has more "local" environmental information than other global sources.

- Weber, Susan (ed.), 1988. *USA by Numbers. A statistical portrait of the United States.* Zero Population Growth, Washington, DC. $9.95 in 1991. An update is in progress using the 1990 census. A Teaching Kit is available to accompany the book, total cost $19.95, book included.

- World Resources Institute, 1990. *World Resources 1990-91.* Oxford University Press, New York. Updated every two years, each edition with analysis of trends in certain issues as well as data tables to support the text. Not all environmental issues in every edition.

- Brown, L., Durning A., Flavin, C., French, H., Jacobson, J., Lenssen, N., Lowe, M., Postel, S., Renner, M., Ryan, J., Starke, L., and Young, J.. 1991. *State of the World 1991.* World Resources Institute, Washington, D.C. Annual summary of global trends in specific environmental issues. Some graphs, but mostly experts' analyses of a wide body of research on the topics. Probably the most widely quoted source of information on environmental trends.

- United Nations Environment Programme, 1989. *Environmental Data Report.* Blackwell, Inc., Cambridge, MA. 547 pp. Graphs and data tables by continent and country for numerous trends in pollution, resources, population, health, energy, waste, transportation, and natural disasters.

- Boden, T.A., Kanciruk, P., and Farrell, M. P.. 1990. *Trends '90.* A compendium of data on global change. Carbon Dioxide Information Analysis Center, Oak Ridge, TN. 264 pp. Free. Data tables and graphs from frequently used research reports on atmospheric CO2 and methane concentrations, sources of emissions, and temperature trends.

For local and regional data, consult your state agencies. In Ohio, for example, the Ohio Department of Natural Resources (ODNR) has disk and hard copy data on water quality, maps and data from the Ohio Capability Analysis program about land uses, utility services, and physical characteristics of most counties, plus maps of state features from the Geological Survey, Natural Areas and Preserves, and Division of Wildlife.
The Division of Water also publishes a free Monthly Water Inventory with precipitation, stream flow, lake levels, etc..

The daily newspaper in a large city will often print a compilation of weather data for a given year in early January of the following year. This is a good source of historical information and good graphic analysis.

Global Change Education Technology Fact Sheets are produced by the School of Natural Resources and Educational Studies at The Ohio State University. For more information about other technology fact sheets, contact Dr. Rosanne W. Fortner, OSU School of Natural Resources, 2021 Coffey Road, Columbus, OH 43210. Phone 614/292-2265. FAX 614/292-7162.
C. A. Havel. Editor. (4/91)

JEdI Activities Summary

The following describes the written activities designed by teachers in 1990 to engage learners in use of the science databases and satellite images on JEdI discs. New activities are expected to be added regularly as more teachers become familiar with the capabilities of the system.

For more information about JEdI, contact Dr. Robert Ridky, JEdI Teacher Coordinator, Office of Technology Liaison, 4312 Knox Road, University of Maryland, College Park, MD 20742. Phone (301) 405 4090.

Introduction to the Activities

Each activity has an abstract which describes the scope of what the activity is intended to accomplish. In this section is a short description of some of the skills developed through the use of an activity. Each one of these activities will develope some skill or skills which will enable the investigator to advance to a higher level of data base acquisition or image processing.

Developing a Physiographic Map of North America

This is an excellent introductory activity to become familiar with the GNA program. After using a tutorial, this activity demonstrates the imaging and profiling capabilities of GNA.

Modeling Coastal Flooding

In addition to conducting coastal flooding scenarios, this activity demonstrates how a color palette can be changed and used. By changing the way the computer images topography, the investigator changes the way features are perceived.

Biomes: Detecting Vegetation Through Remote Sensing

Investigators wse remotely sensed vegetation indices. These vegetations indices are analyzed and then modified. Used with AVHRR imagery this will introduce students to remotely sensed images, how they can be enhanced, and what these images show.

A Comparison Between Topography and Gravity Anomalies

Illustrates how to use the powerful profiling feature of GNA. Topographic and gravity profiles are created, compared and analyzed.

Changing Ozone Levels in the Earth's Atmosphere

This activity shows how ozone data can be applied to maps. Isolines are drawn for Dobson units, which reinforces the use of isotherms and isobars.

Earthquakes: Interpreting First Motion from Seismograms

Investigators discover the use of first motion spheres is seismic studies. Knowledge of seismograms and earthquake motions will be applied to maps and analyzed for their effects upon the land's surface.

Temperature/Salinity Profiles of the Pacific Ocean

This dataset provides investigators the ability to access Pacific Ocean salinity and temperatures. The program's graphing routine allows these data to be displayed in an understandable and usable format.

Identifying Atoms and Molecules in Comets

In addition to two comet spectra, a calibration spectrum is provided. The investigator can access, analyze, and compare spectra of comets to known elements.

Antartica: Three Views

The investigator will be able to study Antartica with three different satellite views. A unique feature of this activity is the access and study of the mosaic of the entire continent and the analysis of sea ice data.

Enhancing Voyager Images

This activity introduces the investigator to powerful image processing and display tools. Two programs, IMDISP and PCMIPS, are used to view Io, one of Jupiter's moons, and to enhance and analyze its features.

Sea Floor Features: Analyzing and Mapping the Ocean Floor

This activity demonstrates how imagining techniques enhance wnderwater features. Using sonographs, features in the Gulf of Mexico are enhanced, measured, and mapped.

Global Change Education Technology Fact Sheets are produced by the School of Natural Resources and Department of Educational Studies at The Ohio State University. For information about other technology fact sheets, contact Dr. Rosanne W. Fortner, OSU School of Natural Resources, 2021 Coffey Road, Columbus, OH 43210. Phone 614/292-2265. FAX 614/292-7162. (4/91)

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GLOBAL CHANGE EDUCATION

Technology Fact Sheet

Getting to know -- JEdI

The Joint Education Initiative (JEdI) project is designed to empower teachers and students with real and current scientific data. Databases made available by the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS) have been given to education. These data sets, through the medium of CD-ROM technology and IBM or Mac][series computers, have the potential to change how science is taught.

Project History

In early 1990 the USGS initiated a feasibility study of the JEdI project. Approximately 30 teachers from the Washington, DC, area were invited to become familiar with databases from NASA, NOAA and USGS. The teachers were overwhelmingly in favor of the project and suggested a range of scientific information to be included on three 700 megabyte JEdI discs.

In the summer of 1990 twenty teachers from across the nation participated in the JEdI Teachers Summer Workshop. Using what scientists use on a daily basis -- i.e., digital image enhancement techniques -- workshop participants developed classroom activities that utilize the power of the technology and enable teachers to bring scientific research data sets to the classroom. The summer workshop teachers had the opportunity to work directly with scientists, acquire other CDs for their own uses, and contribute to a final published set of activities.

Status in 1991

The JEdI activities drafted by the teachers were edited and printed in looseleaf format for initial distribution with the CD set. The CDs themselves required user-friendly menu driven software to be placed directly on the discs. Together the materials are being reviewed by scientists for accuracy and by other teachers for classroom effectiveness.

During the 1990-91 academic year, JEdI staff presented the concept in short courses and workshops at numerous local, state, and national meetings of teacher organizations. The education community is intrigued by the possibilities and eager to develop capabilities for use of this remarkable tool. An electronic bulletin board has been established for project participants and other interested educators and scientists, to facilitate sharing of new ideas.

The activity list on the back of this sheet shows the kinds of data on the discs and the classroom applications designed to date. The databases are varied, broad and deep. Planetary images can be accessed, processed and displayed, and even captured to other output devices such as a hard disk or printer. The powerful access software used with the *Geophysics of North America* disc can be used to study topics such as satellite vegetation indices and the relationship between gravity, magnetic anomalies, and crustal stress. The data sets have opened a new era in what science means to the student and in what scientists can offer the classroom.

On the JEdI horizon

JEdI staff anticipate implementation on a national basis. This will require increased industry support for hardware and increased technological assistance to teachers for its use. In the early '90s the typical classroom computer is incapable of handling CD technology, and the typical teacher lacks knowledge to facilitate computer use beyond minimal word processing and commercial simulations. New tools require new training.

Conceptually the JEdI program is striving for alignment with Project 2061 goals, believing with that effort that scientific literacy of future generations can be improved. JEdI also continues to work toward activity designs that cross disciplines and address topics on several grade levels.

A successful JEdI project will enable teachers and students to augment the school learning environment. This enrichment of the learning process will have far-reaching effects. Democratization of scientific information can impact how science is viewed--that it is knowable by all but is still mysterious and unpredictable.

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317